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THE SHIELDED ARC PROCESS OF WELDING.

BY J. C. LINCOLN.*

Metallic art welding first came into somewhat general use in 1914 and 1915 when the cylinders of some interned German warships were blown up by their crews to prevent them from becoming useful to the United States or the Allies. Repairs on these cylinders were made by the metallic arc process at that time which brought the process to the attention of the country somewhat earlier than would have been the case otherwise. These repairs were made by the use of bare wire and, in general, metallic arc welding has used bare wire electrodes in this country almost entirely to the exclusion of covered electrodes up to within the last year or two. This is in contrast with metallic arc welding abroad. Abroad most of the welding has been done with wire rather heavily covered with a coating consisting largely of asbestos yarn.

* Chairman of the Board, The Lincoln Electric Company, Cleveland, Ohio.

This heavy covering of asbestos yarn and other slag material protects the arc to a considerable degree from the action of the atmosphere and as a result more ductile welds were in general made abroad than in this country.

The use of bare wire for metallic arc welding results in a weld of high tensile strength but of rather low ductility. For most classes of work a weld of this characteristic is entirely satisfactory and the extension of the use of metallic arc welding using bare wire has been extremely rapid in the United States. However, for some classes of service not only high tensile strength is desired but high ductility as well and when high ductility is demanded the bare wire metallic electrode is not satisfactory.

The so-called " Shielded Arc" process produces, however, a weld which has a tensile strength equal to or superior to the bare wire weld and a ductility approaching that of the parent metal. The reasons for the lack of ductility of bare wire welds and the reason why ductility is obtained with the shielded arc process can be briefly set forth in what follows:

In welding bare wire most of the carbon and manganese in the welding rod is oxidized out in passing across the arc. Numerous chemical analyses of the deposited weld metal indicate that the proportion of carbon and manganese in the weld metal is very much less than in the rod from which the weld metal came.

There has been a great deal of discussion as to why the bare wire metallic arc weld is brittle. Some investigators lay the blame at the door of the action of nitrogen on the iron but it seems to me more reasonable to attribute the trouble to oxygen. We know absolutely that the carbon and manganese are mostly oxidized out. Carbon and manganese together do not constitute much over 1/2 per cent of the welding rod and therefore, it is entirely reasonable to expect that the same oxygen which burnt out the carbon and manganese will act on the 99 per cent of iron and produce a noticeable quantity of iron oxide. This iron oxide would be dissolved in the weld metal and can be expected to produce a resulting lack of ductility. However, from a practical standpoint, it makes no difference whether the brittleness is caused by the oxygen of the atmosphere or by the nitrogen of the atmosphere. If we want to get rid of the effects we will have to change the atmosphere around the arc.

Many years ago, the writer produced a nitrogen atmosphere around the arc. This atmosphere increased the ductility, but the ductility of the weld metal produced in a nitrogen atmosphere does not approach the ductility of the metal produced by the so-called Shielded Arc process. Instead of a neutral atmosphere at the arc, experience has shown that a *reducing* atmosphere is required to obtain the desired result. In the case of the metallic arc this reducing atmosphere is obtained by the use of a heavy coating around the wire of such a nature that it produces a reducing atmosphere around the arc.

The breaking down of the coating produces so far as we know, some hydrogen, some carbon monoxide, and some hydrocarbon gases. The exact nature of the atmosphere around the arc has not been analyzed.

The statement that hydrogen is present is made on account of the fact that the voltage across the arc using the heavy coatings varies from 30 to 35 volts while the same wire with the same current without the coating will have a voltage of from 17 to 20 volts across the arc. Those of you who have experimented with the arc in various gases, know that the presence of hydrogen atmosphere around the arc greatly increases the voltage across the arc. In a pure hydrogen atmosphere from 60 to 80 volts is necessary to maintain an arc. From a practical standpoint, however, a pure hydrogen atmosphere is undesirable because the arc is so wild that it would be impossible to control it. Therefore, from a practical standpoint, it is necessary to provide materials and coatings around the electrode such that there will be enough hydrogen to increase the voltage across the arc and give a stronger reducing action at the arc and enough carbon monoxide to prevent the voltage across the arc becoming too high and the arc becoming too wild.

As a matter of fact the development of the coating around the wire has been made by the method of trial and error.

Electrodes with a good thickness of coating and a good composition have been tested in actual welding, the voltage across the arc being noted, coating noted, penetration noted, amount of splatter noted, then change in the composition of the coating is made in the direction which is hoped will improve the operating characteristics.

As a result of many thousands of experiments a wire has been developed by the company with which the writer is connected, called "Fleetweld" which produces weld metal having a tensile strength greater than the parent metal and ductility approaching that of the parent metal.

Figure 1 shows a number of samples butt welded with this wire which were pulled in a tensile testing machine to demonstrate the tensile strength of the weld metal and its ductility.

It will be noted in order to secure breaking of the coupon specimen in the weld that holes were bored through the weld metal. These specimens then broke in the weld metal at a tension ranging from 65,600 to 75,100 pounds per square inch, on the weld metal.

This is a practical way of showing that the tensile strength of the weld metal is greater than the parent metal and at the same time the elongation of the holes drilled through the weld metal indicate the ductility of the weld metal. These holes you will see are nearly twice as long in the direction of the pull as they are at right angles to the direction of the pull indicating at this particular spot an elongation of from 75 to 80 per cent. It should be carefully borne in mind that this elongation of 75 to 80 per cent in about 1/8 inch does not indicate that an elongation of 75 to 80 per cent can be expected in 2 inches. As a matter of fact, in pulling a 2 inch sample and noting its ductility, the actual stretch will not be even throughout the two inches but will tend to concentrate at some one spot. This is simply another way of saying that the per cent of elongation which will be obtained with a 2 inch sample is greater than will be obtained with an 8 inch sample.

Figure 2 is a photograph of a strip of practically pure weld metal which has been twisted and bent as shown indicating the ductility of the deposited metal.

In addition to the increased ductility which is obtained by the use of the Shielded Arc another advantage is obtained by the Shielded Arc process as compared with the bare wire welding process. Those of you who have had occasion to use bare wire electrode welds which are repeatedly heated and cooled, know that something happens to the bare wire welds during the repeated heating and cooling which can be described by saying that the weld metal "rots." Cracks in the weld metal will appear on

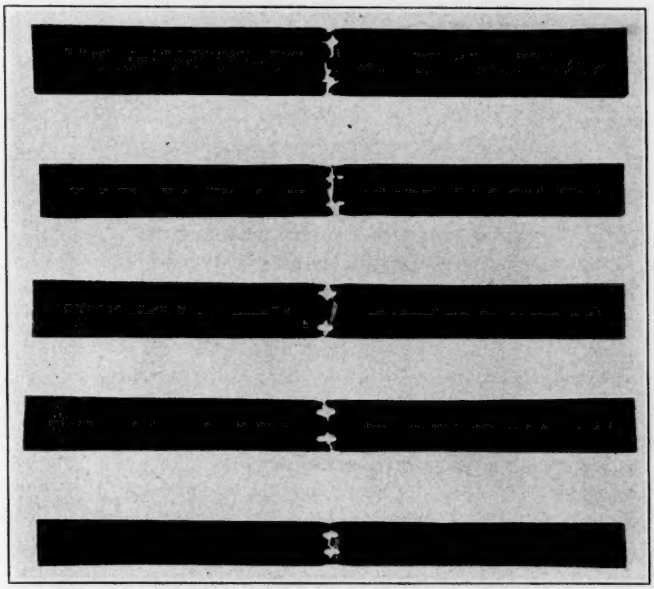


FIGURE 1.—A NUMBER OF SAMPLES BUTT WELDED WITH FLEETWELD, PULLED IN A TENSILE TESTING MACHINE TO DEMONSTRATE TENSILE STRENGTH OF WELD METAL AND ITS DUCTILITY.

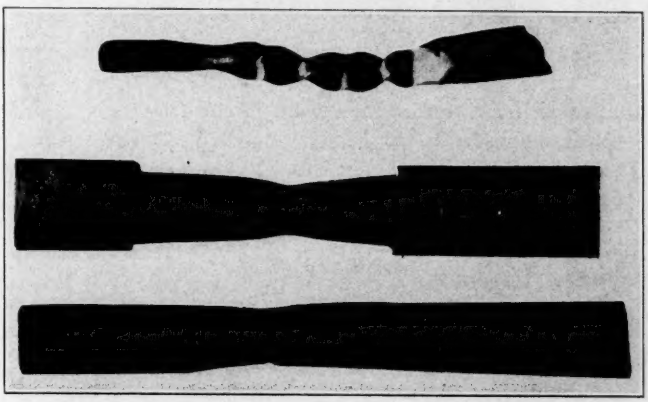


FIGURE 2.—A STRIP OF PRACTICALLY PURE WELD METAL WHICH HAS BEEN TWISTED AND BENT TO SHOW DUCTILITY OF DEPOSITED METAL.

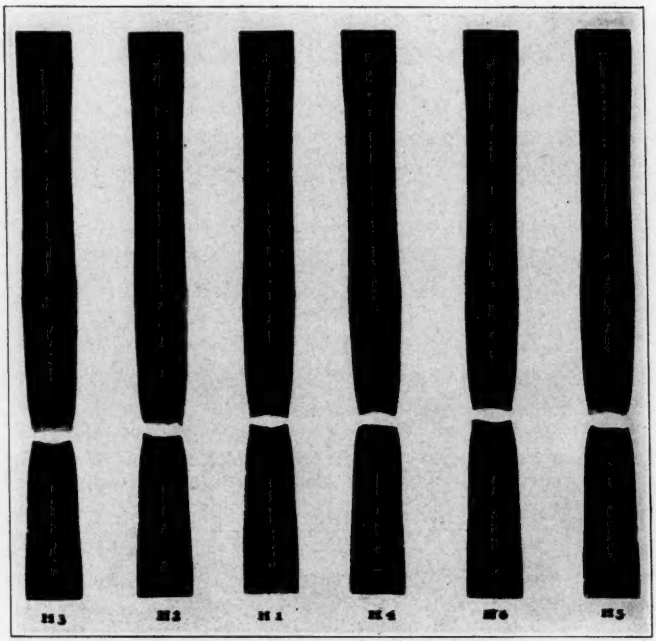


FIGURE 3.—A SERIES OF COUPONS MADE BY THE SHIELDED ARC CARBON ARC PROCESS.

H-3 pulled without altering the weld in any way.
H-2 excess metal on one side of weld ground off.
H-1 both beads ground off flush.
H-4 both beads off with one hole drilled through weld metal.
H-5 and H-6, fracture occurred outside of weld.

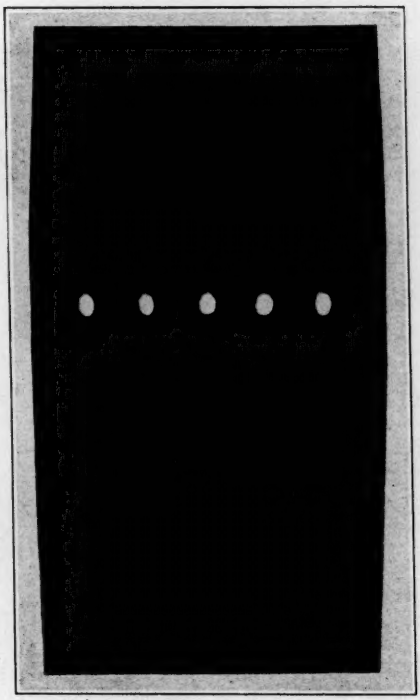


FIGURE 4.—A SEGMENT (FULL SIZE) OF TEST BAR H-5 SHOWING ELONGATION OF HOLES DRILLED IN WELD.

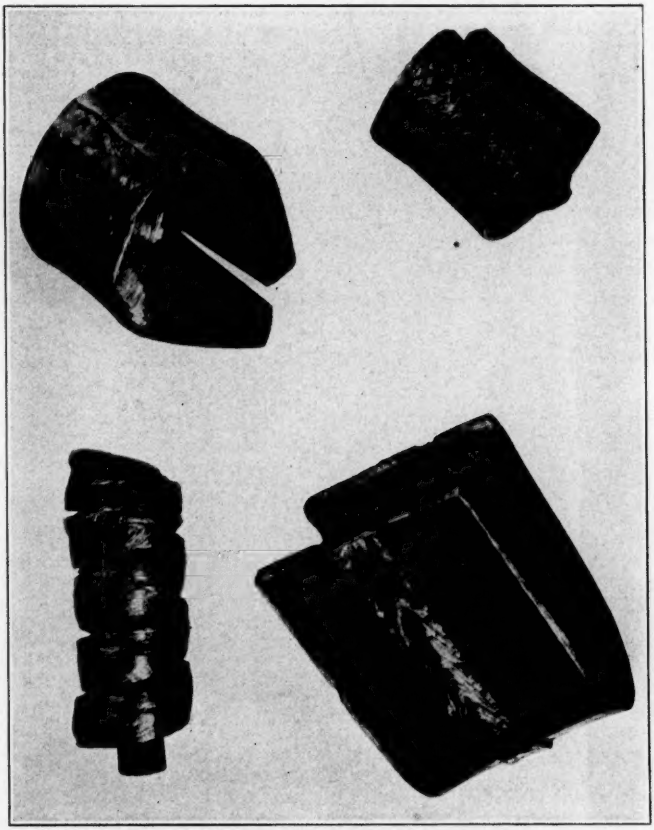


FIGURE 5.—A SERIES OF SPECIMENS BENT AND TWISTED TO SHOW DUCTILITY OF WELDS MADE BY FLEETWELD PROCESS.

repeated heating and cooling which rapidly get deeper until finally the weld breaks by cracking clear through.

Further experiment has shown that a bare wire metallic arc weld is of such a nature that when it is desired to enamel over it that bubbles appear under the enamel at the line of the weld which prevents the enamel from fulfilling its ordinary function.

For a number of years gas was used for making welds which were to be enameled because the coating would blister over the metallic arc weld. Whether the cause of the cracks in the case of repeated heating and cooling and the cause of the blistering in the case of enamel are due to the same fundamental cause in the bare wire metallic arc weld is of minor importance from a practical standpoint because experiment has shown that welds made by the Shielded Arc process are not heir to either of these troubles.

Shielded Arc metallic arc welds can be repeatedly heated and cooled without effecting the welds any more than they effect the parent metal.

Enamel can be applied over Shielded Arc welds without blistering any more than they blister on the parent metal.

CARBON SHIELDED ARC WELDS.

The Company with which the writer is connected has placed on the market an automatic machine for carbon arc welding which in general has the advantage over metallic arc welding in that the process is quicker and that no preparation of the edges to be welded is necessary.

Years ago when the carbon arc was first applied to welding of pipe, for instance, the carbon arc welds did not have the ductility that the parent metal had.

Many experiments conducted throughout a number of years have made possible at the present time carbon arc welding in which the atmosphere around the arc is controlled and in which the ductility of the weld is practically equal to that of the parent metal, while the tensile strength is also equal to, or greater than that of the parent metal.

This atmosphere is obtained by introducing into the arc a specially prepared and impregnated wood fibre string. From this string as it is burned there will be developed some water vapor,

a large amount of hydrocarbon gases, some carbon monoxide, and on the outside of the flame carbon dioxide. The water vapor will be acted upon by the carbon electrode and broken down into carbon monoxide and hydrogen. The hydrogen will have a powerful reducing action on the metal which is being washed from one side of the crater to the other by the action of the carbon arc.

Figure 3 shows a series of coupons made by the Shielded Arc, carbon arc process. Sample H-3 was pulled without altering the weld in any way. Sample H-2 has the excess metal on the one side of the weld ground off. Sample H-1 has both beads ground off flush. Sample H-4 both beads ground off with one hole drilled through the weld metal.

Even when three and five holes were drilled through the metal as shown in H-6 and H-5, the fracture occurred outside of the weld.

Figure 4 shows a segment (full size) of test bar H-5 showing elongation of holes drilled in weld. The distortion of the originally round drill holes is due to stretch in the weld metal—a graphic proof of the high ductility of the weld metal.

Figure 5 shows a series of specimens bent and twisted to show the ductility of the welds made by this process.

These figures indicate that the carbon arc process for high speed automatic work gives a weld metal of high tensile strength and high ductility.

Figures 1 and 2 indicate that for the hand metallic arc process similar tensile strength and high ductility are obtained by the manual welding process.

The results of this work indicate that if iron is exposed at high temperatures to a reducing atmosphere that the quality of the iron is actually improved in passing across the arc in the case of the metallic arc and in passing from one side of the crater to the other in the case of the carbon arc.

The introduction of hydrogen into the atmosphere around the arc increases the voltage across the arc in the metallic arc welds from an average of 17 to 18 volts to an average of 30 volts. This increase in voltage means that nearly twice the heat is developed at the arc with the same current in the case of the heavily coated electrodes, as is developed with the ordinary bare wire electrodes.

As a consequence the speed of welding with a heavily covered electrode will be very much greater than with the bare wire electrode with the same current.

The cost of the weld, of course, is made of two items, first—the labor, and second—the cost of electrode, current, etc. In most cases the labor is by all means the predominating item of cost. In general labor will account for at least three fourths of the cost of the ordinary weld.

It is evident that a heavily covered electrode must cost more per pound of steel than a bare wire electrode but if the heavily covered electrode can reduce the labor cost of doing the welding, it is possible that the use of the more expensive electrode may be cheaper than the use of the bare wire electrode.

Experiments with the use of thousands of pounds of this heavily covered electrode in the welding of pipe lines and other appliances indicates that the total cost of welding with expensive electrode is less than the total cost of welding with the cheaper bare wire electrode, and that the improved quality of the weld is obtained not only for nothing but for less than nothing.

To put it another way—the heavily covered electrode gives a weld of high ductility and high tensile strength at less cost than it was possible to get with the bare wire welds formerly used.

The Navy Department are to be congratulated in permitting the use of high grade welding for the manufacture of high pressure steam drums. Twenty-four such drums were built by the Navy on Navy Specifications before the Boiler Code Committee of the A. S. M. E. brought out their specifications for welding boiler drums by the electric arc process.

The writer is very certain from his acquaintance with the work of the Boiler Code Committee that the fact that the Navy passed these welded drums greatly accelerated the action of the Boiler Code Committee in the preparation of their welding code for boiler drums.

In this case the Navy Department has set the pace for industry to follow in the use of high grade welding for high pressure vessels.

SOME COMPARISONS IN PROPELLER DESIGN METHODS.

By Commander H. F. D. Davis, U.S.N., Member.

The student of propeller design, particularly in beginning his inquiries, is much confused by the considerable differences in nomenclature of the authorities who write on this subject. Besides differences found in going from writer to writer, it is also found that the symbols of a given writer are changed from one book or paper to another.

In an attempt to clarify ideas, to establish the relationship of the various symbols and definitions, and as an "aide memoire" for ready reference while reading miscellaneous articles the writer has compiled Table I. It is believed that the method of presentation developed in this tabulation may be of use, by providing guide-posts, to others who are now, or may later be, undertaking a course of study in this interesting subject.

In addition to presenting and explaining Table I in detail and showing the relation of the symbols and formulae of the different authors to their design methods, the same problem has been worked out by each method to illustrate more graphically the similarities and differences, and to show how the results of the methods compare when applied to a practical design problem.

Mr. R. E. Froude's method has been taken as representative of the British practice, Dr. Ing. Karl Schaffran's and Dr. Ing. Wilhelm Schmidt's as typical of the German, and Rear Admiral Dyson's and Rear Admiral D. W. Taylor's as typical of American practice.

Rear Admiral D. W. Taylor's method (See Column 2 of Table I).

Admiral Taylor's recent work [1] has been used as his type method

[1] (a) Propeller Design Developments—D. W. Taylor—presented to the World Engineering Congress, Tokyo, published in The Shipbuilder, April, 1930.

(b) Model Results of a Four Bladed Propeller Series—D. W. Taylor, Proc. American Society of Naval Architects and Marine Engineers, 1929.

rather than the presentation of the subject in his "Speed and Power of Ships," inasmuch as this recent work has been developed especially to meet the needs of the modern propeller designer. The earlier publication gives the results of the research work on model propellers carried out in the Washington Tank, but the curves therein are not so convenient for use in analysis and design work.

Dr. Schaffran's Method (See Column 3 of Table I).

Dr. Schaffran's published results [2] of the systematic model propeller research work done under his direction at the Berlin tank form the bases for a number of German methods of design and analysis. It is fortunate for readers of English who do not also command German that he has written an article [3] in English which is practically a treatise on the subject. Dr. Schaffran presents the data obtained in the tank in forms particularly convenient to the designer.

Froude Method (See Column 4 of Table I).

Mr. R. E. Froude's research work has formed the basis for most of the British methods of propeller analysis and design, his nomenclature and treatment having been widely adopted. His latest paper [4] brought up to date and modified slightly the results and treatment of his earlier papers.[5]

Dr. Schmidt's Method (See Column 5 of Table I).

Dr. Schmidt's method [6] comprises a special logarithmic treatment of Dr. Schaffran's research results by means of which the number of sheets of curves has been greatly reduced, the results for three-bladed propellers being given on 4 sheets, the results for four-bladed propellers on one sheet, and the results for two-bladed propellers on two sheets. This method of analysis and design is followed in a number of current German technical publications by

[2] Systematische Propellerversuche, Karl Schaffran—Strauss, Berlin, 1916.

[3] The Influence of Propeller Revolutions upon the Propulsive Efficiency of Merchant Ships—K. Schaffran—Northeast Coast Institution of Engineers and Shipbuilders in Scotland, 1923-24.

[4] Results of Further Model Screw Propeller Experiments—R. E. Froude—Institution of Naval Architects, 1908.

[5] (a) A Description of a Method of Investigation of Screw Propeller Efficiency—R. E. Froude—I. N. A., 1883.
(b) The Determination of the Most Suitable Dimensions for Screw Propellers—R. E. Froude—I. N. A., 1886.

[6] Zusammenfassende Darstellung von Schraubenversuchen (Summarized Description of Propeller Experiments)—V. D. I.—Verlag G. M. B. H., 1926, Berlin NW7.

writers on the subject of ship trial analysis and propeller design.

Admiral Dyson's System (See Column 6 of Table I).

The latest edition of Admiral Dyson's book [7] sets forth in detail his method of solving propeller problems.

GENERAL DESCRIPTION OF TABLE I AND THESE ANALYSIS AND DESIGN METHODS.

It will be noted that the definitions are given in the left hand column of Table I, and the symbols and equations are given in the other columns under the names of the different authorities. The definitions are those which appeared adequate to the writer. The definitions are grouped so as to bring together those bearing on the same or related subjects, beginning at the top with the physical dimensions of the propeller and ending with the coefficients which are used as arguments with the curves.

The Froude, Taylor and Dyson symbols and equations are expressed in the usual British units: horsepower, foot, pound, knot, *revolutions per minute,* etc., except as noted, and the Schaffran and Schmidt symbols and equations are given in metric units: meter, kilogram, *revolutions per second,* metric horsepower, etc., with exceptions noted. The horsepower in the metric system, equal to 75 kilogrammeters per second, is 98.6 per cent of the horsepower in the British system.

The Froude, Taylor, Schaffran and Schmidt methods are alike in that they utilize the results of systematic model propeller experiments plotted as curves. Admiral Dyson is alone in basing his method on empirical curves obtained from the trials of full sized ships. The similarities and differences of the four first mentioned systems therefore more naturally lend themselves to parallel comparison, while Admiral Dyson's method shows more marked differences.

The Froude, Taylor, Schaffran and Schmidt methods are alike in requiring the determination of values for wake and thrust deduction fractions suitable to the case in hand before the equations can be set up and the coefficients determined with which to use the model experiment results (curves) in solving a design

[7] Screw Propellers—C. W. Dyson—1924. Simmons-Boardman Publishing Company.

No.	DEFINITIONS
	GEOMETRICAL AND PHYSICAL CHARACTERISTICS
1	Diameter of propeller.
2	Pitch of propeller.
3	Pitch ratio.
4	Diameter of hub.
5	Disc area.
6	Developed(blade) area outside of hub.
7	Projected area outside of hub.
8	Developed (blade) area ratio.
9	Projected area ratio.
10	Mean width ratio.
11	Blade taper and width factor.
12	Blade thickness at radius.
13	Blade thickness fraction (root).
14	Number of blades.
	PERFORMANCE DATA OF SHIP AND MODEL.
15	Speed of ship (propeller) through still water.
16	Speed of advance (of propeller through wake value.
17	Revolutions per minute.
18	Revolutions per second.
19	Shaft horsepower.
20	Effective horsepower (Model basis results).
21	Useful (thrust) horsepower.
	FACTORS AND COEFFICIENTS RELATING PROP
22	Wake fraction.
23	Thrust deduction fraction.
24	Thrust of propeller.
25	Torque of propeller.
26	True slip.
27	Apparent slip.
28	Resistance of ship at trial speed.
29	Propulsive coefficient.
30	Propeller efficiency.
31	Hull efficiency.
32	Suction efficiency.
	FACTORS AND COEFFICIENTS RELATING PROP
33	Moment (Momentum) constant.
34	Thrust (Schuh) constant.
35	Basic 'P' coefficient.
36	Basic 'U' coefficient.
37	Speed coefficient.
38	Performance (thrust-speed, diameter-base coef
39	Torque (thrust-speed, revolution basis coefficie
40	Performance (moment-speed, diameter torque coef
41	Torque (moment-speed, revolutions torque coefficie
42	Abscissa values 'x'
43	Ordinate values 'y'
44	Abscissa values 'x_1'
45	Ordinate values 'y_1'
46	Coefficient.
47	Basic slip.
48	Power loss factor.
49	Tip speed
50	Basic speed
51	Basic shaft horsepower
52	Shaft horsepower per sq in disc area.
53	Basic propulsive coefficient.
54	Basic effective horsepower.
55	Hull load factor.
56	Hull load fraction.
57	Screw load factor.
58	Screw load fraction
59	Speed factor.
60	Speed fraction.
61	Apparent slip.

TABLE 1.

DEFINITIONS AND CORRESPONDING SYMBOLS AND EQUATIONS.

	SYMBOLS AND EQUATIONS.				
	TAYLOR.	SCHAFFRAN.	FROUDE.	SCHMIDT.	DYSON.
CHARACTERISTICS					
	d measured. ft	D measured inches	D measured ft	D measured inches	D measured ft
	p face pitch measured. ft	H face pitch measured inches	P(diameter $\times$ 1.42) face pitch ft	H face pitch measured inches	P face pitch measured ft
	$a = p \div d$	$H \div D$	$p = P \div D$	$H \div D$	$P \div D$
	Number of blds.	A inches	Num. of blds.	A inches	Num. of blds.
e of blds.	$T d^2 \div 4$ Sq. ft	$A \cdot T D^2 \div 4$ Sq. in.	$T P^2 \div 4$ Sq. ft	$F \cdot T D^2 \div 4$ Sq. in.	$T P^2 \div 4$ Sq. ft
	Developed area. Sq. ft	A_d Sq. in.		R Sq. in.	BA Sq. ft
	Projected area.	A_p Sq. in.			PA Sq. ft
	Developed area ratio.	$A_d \div A = \zeta_1$	Disc area ratio	$\zeta \div F$	$BA \div BA$
	Projected area ÷ Disc area.	$A_p \div A$			$PA \div BA$
	Mean width ratio.				
			$B = 0.2 \sqrt{p}(r - 2.5)$		
	Blade thickness at gage	t_g inches		t_g inches	
	Blade thickness fraction	$\zeta \div D$		$\zeta \div D$	
				$P \cdot Y \div 12$ = mean face pitch	
P AND MODEL.					
ed scale.	$V = V_s \div (1-r)$ Knots	v_s (Knots) $\cdot$ dist. $= V_s$ (same period)	V $V_s (1+s)$ Knots	$v_s = \zeta \cdot V_s = \zeta (1+r)$	V Knots
ough wake scale	$V_s = V_s (1-r)$ Knots	$\zeta_s = \zeta_s (1-r)$ kt	V_s $V_s (1+s)$ Knots	$\zeta_s = \zeta \cdot V_s = \zeta (1+s)$	
	R	$60n$	$R = 60n$	$60n$	$R_n = 60.38 \sigma \div P (1-d)$
	$R \div 60$	n		n	$R_n \div 60$
	$P = 2 \cdot T \cdot R \cdot Q \div 33000$	$HPS = 2 \cdot T \cdot n \cdot M \div 75$	$SHP = 2 \cdot T \cdot n_s \cdot$ torque $\div 550$	$HPS = 2 \cdot T \cdot n \cdot M \div 75$	$SHP_n = SHP \div \delta^{3.5}$
o model.	$E = WV \div 326$	$EPS = W v_s \div 75$	$EHP = \rho V \div 326$	$EPS = W v_s \div 75$	ehp
	$U = TV \div 326 = E \div (1-r) \div (1-t)$	$SPS = S v_s \div 75$	$H = TV \div 326$	$SPS = S v_s \div 75$	
S RELATING DIMENSIONS AND PERFORMANCE DATA.					
	$\sigma = 1 - (\zeta \div V)$	$\sigma = 1 - (\zeta \div 60) = 1 - (\zeta_s \div v_s)$	$\sigma = (V \div V_s) - 1$	$\sigma_s = \zeta \div \zeta = (1 - \sigma)$	
	$t = 1 - (E \div T)$	$t = 1 - (EP \cdot 33 \cdot 1 - t = (EP \cdot 33$	$t = 1 - (\rho \div T)$	$t_s = EPS \div \zeta = (1 - t)$	
	$T = R \div (1-t)$ lbs.	$S = W \div (1-t)$ Kg.	$T = \rho \div (1-t)$ lbs.	$S = W \cdot g$ Kg.	
	$Q = P \cdot 33000 \div 2 \cdot \pi \cdot R$ ft. lbs.	$M = 71.62 HPS \div 2 \cdot \pi \cdot n$ Kg. m.	Torque ft. lbs.	$M = 71.62 HPS \div 2 \cdot \pi \cdot n$ kg. m.	
	$1 - (EP.33 V \div R_n)$	$S_s = 1 - \zeta \div \pi H$	$S = (T - R) \div R$		
	$1 - (EP.33 V \div R_n)$	$S_s = 1 - \zeta_s \div \pi H$			d_1 see lines 17 and 61
mod.	$R = T (1-t)$ lbs.	$W = S (1-t)$ Kg.	$\rho = T (1-t)$ lbs.	$W = S g_s$ Kg.	
	$E \div P_n \cdot \eta = (1-t) \div (1-\sigma)$	$71620 \cdot EPS \div HPS = \eta_s \div \eta_s$	$EHP \div SHP$	$\eta = \eta_s \cdot \eta_s \cdot \eta_s$	$ehp \div SHP_n$
	$n_s = T V_s \div P_n 326$	$\eta_s 2420 = EPS \div HPS$	$TV \div SHP \cdot 326 = \rho V_s \div 0.2 \cdot \pi \cdot n$	$\eta_s = \zeta \cdot \zeta \div 2 \cdot \pi \cdot M$	
	$(1-t) \div (1-\sigma)$	$\eta_s = \eta_s \div \eta_s = (1-t) \div (1-\sigma)$	$(1-t) \div (1-\sigma)$	$\eta_s = \eta_s \cdot \eta_s$	
				$\eta_s = \eta_s \cdot \eta_s \cdot 1 - t$	
S RELATING DIMENSIONS AND PERFORMANCE DATA TO PROPER CURVES.					
ent.	$C_n = Q \div (R^2 \cdot D^5 \cdot \rho)$	$C_n = M \div (\sigma^2 \cdot D^5 \cdot \rho)$			
	$C_s = T \div (R^2 \cdot D^4 \cdot \rho)$	$C_s = S \div (\sigma^2 \cdot D^4 \cdot \rho)$			
	$R_n = R (D \rho \div \mu)^{.5}$				
	$Q_n = R (D^5 \cdot \rho \div \mu)^{.5}$				
	$\delta = R n d \div V_s$	$C_{ss} = n D \div \zeta$	$SD \div V$	$\zeta \div n D$	
Diameter thrust coefficient		$C_d = (2)^2 \div D^2 \zeta$			
ion thrust coefficient		$C_s = n (2)^2 \div (\zeta)^2$			
Diameter torque coefficient		$C_{dn} = M^2 \div D^5 \zeta^2$		$HPS \div \rho D^5 \zeta^3$	
ition torque coefficient		$C_{mm} = M^2 n \div (\zeta)^5$		$HPS \cdot n^2 \div \rho \zeta^5$	
			$\sigma = R_n D \div V$		
			$\gamma = \rho R_n [R_n \div 60 D^2 \rho]$		
			$C_n = P^2 R^2 \div (D^5 \rho)$		
			$C_s = R n \div (D^4 \rho)$		
				$HPS \div \rho D^5 n^3$	
					ζ from sheets 7B, 17B, 28B
					H from sheets 17A, 17B, 18
					$T_s = T \cdot P \cdot R_n$ and sheet 30A
					$\gamma = \frac{2R_n \pi P (1-d)}{V \cdot 60.38}$
					$SHP_n = \frac{P_n \cdot T \cdot R \cdot \pi \cdot R}{326}$ and η (Dyson's formula)
n area.					η_s from sheet 30A
					$P \cdot \eta_s$ from sheet 30A
					$EHP = SHP \cdot \eta_s$
					$ehp \div EHP$
					$\eta_s \div ehp \div EHP$ & Sheet 31
					$ehp \div EHP$
					$\eta_s = \eta_s \cdot \eta_s \cdot \eta_s$ Sheet 31
					$\rho \div V$
					$\eta_s \div \rho V$ Sheet 31
					$\rho = SHP \div HP_s$

problem. Such wake and thrust deduction values may be obtained from self-propelled model tests of the ship concerned, from certain general rules based on systematic self propelled model tests of models of different characteristics, from analyses of trial results of full sized ships leading to general rules, or from the analyses of the trials of a sister ship. At this juncture it may be appropriate to emphasize one of the most important points of similarity and difference in the formulations. This point is that the Taylor and Schaffran definitions of wake are alike, viz, $w = 1 - \frac{V_A}{V}$ and $w = 1 - \frac{V_a}{V_m}$ respectively; likewise the Froude and Schmidt definitions of wake are alike: $w = \frac{V}{V_1} - 1$ and $w = \frac{V_a}{V_a} - 1$ *i.e* $1 + w = \frac{V}{V_1} = \frac{V_a}{V_a}$. The relationship between the two[8] is readily worked out and is shown graphically in Figure 1.

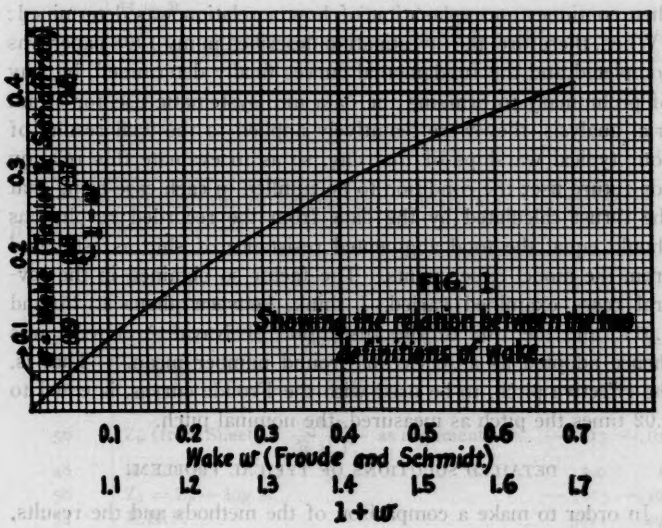


FIG. 1.
Showing the relation between the two definitions of wake.

[8] Speed and Power of Ships, p. 198.

The definition of thrust deduction is the same in all four systems, viz: $\frac{T-R}{T} = t$ (Taylor); $\frac{T-\rho}{T} = t$ (Froude); $\frac{S-W}{S} = t$ (Schaffran); and $\eta_o = \frac{W}{S} = (1-t)$ *i. e.*, $\frac{S-W}{S} = t$ (Schmidt).

The definitions of pitch also require some elaboration. The Taylor, Schaffran and Schmidt curves based on model tests all include the pitch ratio $\frac{(\text{pitch})}{(\text{diameter})}$ as one of the primary variables in which the pitch used is the *face* pitch of the model propeller as measured, also called the nominal pitch. Dyson's system also uses this face pitch. The Froude data from his model tests include the pitch ratio as a primary variable, the pitch value in this case, however, being as Mr. Froude explains,[9] "simply the travel per revolution which is found to give zero thrust; and its relation to the "nominal" pitch is obviously matter for question. . . ." He then continues an explanation of how a relation was determined: "When, therefore, the investigation described in my 1908 paper was completed and the fundamental curves finally determined, by way of preliminary to bringing the data into systematic use for steam trial analysis, they were tentatively applied to the trial results of four typical warships of that day, so as to evaluate this relation for future use; the condition to be fulfilled in each case being that the thrust calculated by the data from the recorded revolutions should equal the total augmented resistance of ship as estimated from the model experiments. The factor so obtained in the several cases examined varied, I think, between about 1.025 and 1.017; and the 1.02 of the Institution of Naval Architects was thence adopted as a serviceable round number mean." That is, the effective pitch, to be used with the Froude curves, is equal to 1.02 times the pitch as measured, the nominal pitch.

DETAILED SOLUTIONS OF TYPICAL PROBLEM.

In order to make a comparison of the methods and the results, the problem solved on pages 364-7 of Admiral Dyson's "Screw

[9] Transactions of I. N. A., 1920, p. 321.

Propellers" will be solved by each of the other methods in turn, the data, and the essential parts of Admiral Dyson's solution, being as follows:

A battleship

Length on load water line	510
Beam	88.22
Nominal Block Coefficient	.594
Coefficient Midship Section	.979
Effective horsepower at 21 knots	15,740
R.P.M., designed	322

SOLUTION BY DYSON METHOD.

Line No. Table I	Formulae		
	H′ ÷ B		.316
	Type		1
	B ÷ L.LWL.		.173
	H ÷ B		.316
	S.B.C.	Sheets 17A, 17B	0.53
	2L.A.B. ÷H′		18.3
47	S	Sheets 17A, 17B, 20B	.1375
	K.B.C.	Sheets 17A, 17B	.597
	R.T.C.	Sheet 19	3.33
48	K	Sheets 17A, 17B, 19	1.0

From consideration of satisfactory clearances the diameter is fixed at 9 feet 2 inches.

1	D	9.17	9.17
15	v (ship trial data)	21	21
20	e.h.p. $= \frac{15740}{4}$ (model trial data)	3935	3935
55	$\frac{\text{e.h.p.}}{\text{E.H.P.}}$ (See line 54 below)	0.7	0.8
56	Z_p (from Sheet 21 $\frac{\text{e.h.p.}}{\text{E.H.P.}}$ as argument)	—.1613	—.1009
48	K	1.0	1.0
58	$Z_g = Z_p \div \log K$	—.1613	—.1009
54	E.H.P.	5621	4920
59	$\frac{v}{V}$ on S = .15 Sheet 22B	.715	.735
50	V	29.37	28.57
	$E.T._D$ Sheet 23-24	6.406	5.898

Line No. Table I			
9	$\frac{PA}{DA}$	.558	.522
53	$P.C._S$	.571	.589
51	S.H.P.	9844	8214
19	$S.H.P._D = \frac{S.H.P.}{10Z_g}$	6790	6514
49	T.S.	12250	11200
1	I—S	.8625	.8625
2	P	8.115	8.634
60	Z_s (1) Sheet 21	.34	.305
61	$s = S \frac{10Z_s}{10Z_g}$	.2075	.22
17	$R_D = 101 - 1/3 \frac{V}{P} (1 - s)$	330.9	316

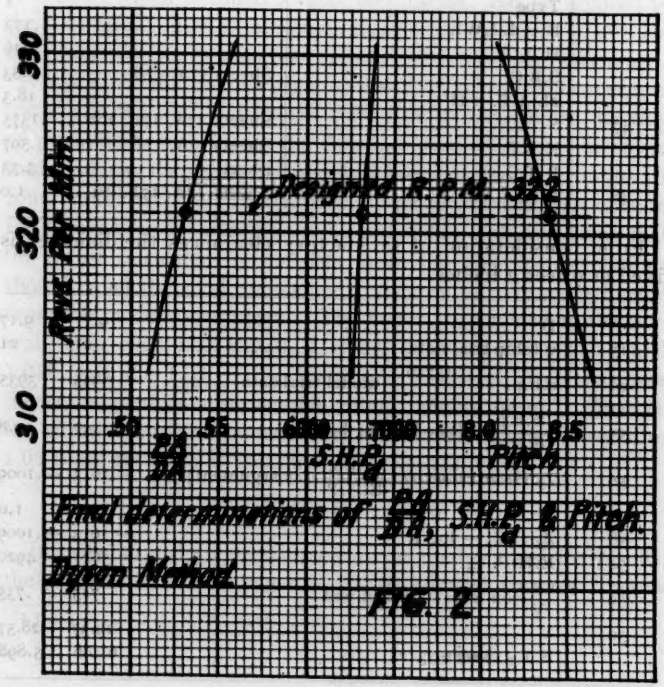


FIG. 2.

Plotting the above values of items (9), (51) and (2) as abscissae on corresponding values of (17) as ordinates, the values, corresponding to the designed revolutions, 322 R.P.M., may be interpolated giving the final solution (See Fig. 2).

D	9.17
P	8.42
$\frac{PA}{DA}$	0.537
S.H.P.$_d$	6625
Total S.H.P.$_d$	$4 \times 6625 = 26{,}500$

For the solutions by the other methods, no limitations as to diameter will be set, and in order that the basic assumptions will be the same in all cases, the Taylor (Schaffran) wake fraction will be taken as 0.20, the corresponding Froude (Schmidt) wake fraction being .249, and the thrust deduction fraction will be assumed to be 0.20.

The Taylor curves for three bladed propellers of 0.25 mean width ratio and 0.05 blade thickness fraction Figs. 1 and 3 of reference 1; the Froude value of B for elliptical blades with disc area ratio equal to 0.4 and C_A, C_o and efficiency values from Appendix 2 of the 1908 paper; the Schaffran curves in Figs. 12 and 14 of reference 2 applying to elliptical blades with $\frac{A_a}{A} = 0.42$ and $\frac{\delta_1}{D} = .05$; and the Schmidt curves Plate 2 of reference 6 for three bladed elliptical blades of $\frac{F_a}{F} = 0.42$ and $\frac{\delta_1}{D} = .05$ are used; these being the closest corresponding curves of the different methods.

The calculations have been carried through with a slide rule to which the formulae are generally well adapted.

SOLUTION BY TAYLOR METHOD.

Line No. Table I	Formulae		
22	w		.20
	1—w		.80
23	t		.20
	1—t		.80
17	N		322
15	V		21
16	$V_A = V(1-w)$	21 × .8	16.8
	$(V_A)^{5/2}$		1157
20	E (from model basin results)	15740 ÷ 4	3935
21	$U = E\ (1-w) \div (1-t)$	3935 .80 ÷ .80	3935
36	$B_{s3}\ \frac{N\ (U)^{\frac{1}{2}}}{(V_A)^{5/2}}$	$322\ (3935)^{\frac{1}{2}} \div (16.8)^{5/2}$	17.46
	From B_{s3} Curves Figure 2 of reference 1 with B_{s3} = 17.46 as argument at most efficient point (See Figure 3 of this paper).		
	a		0.8
	δ		187
37	$d = N\delta \div V_A$		
	$d = \delta\ V_A \div N$	187 × 16.8 ÷ 322	9′.75
	p = ad	.8 × 9.75	7.8
	From B_{p3} Curves Figure 1 of reference 1 with a = 0.8 and δ = 187 as arguments (See Figure 3 of this paper).		
	B_p		22.3
	e_p		.603
35	$B_{p3} = NP^{\frac{1}{2}} \div (V_A)^{5/2}$		
35	$P = (B_{p3})^2\ (V_A)^5 \div N^2$	$(22.3)^2\ (16.8)^5 \div (322)^2$	6325
	4 P	4 × 6325 for 4 shafts	25,300
	A check on the power calculation may be made as follows:		
29	$P = E\ (1-w) \div (1-t)\ e_p$	3935 × .8 ÷ .8 × .603	6525
	4 P	4 × 6525	26,100

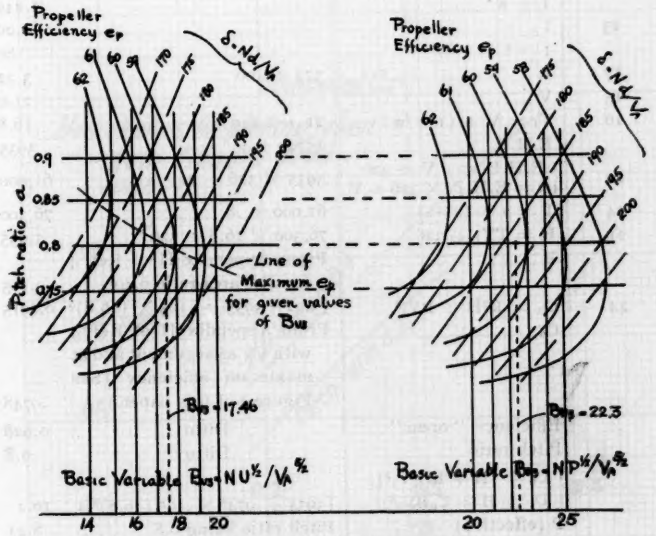
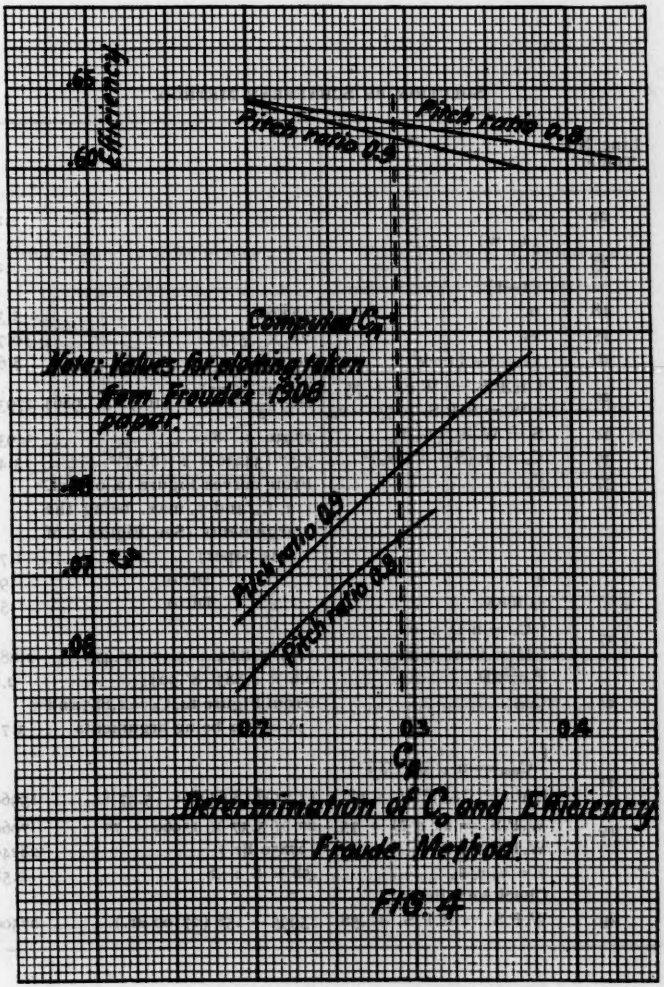


FIGURE 3.—ILLUSTRATION OF THE USE OF TAYLOR'S CURVES.

SOLUTION BY FROUDE METHOD.

Line No. Table I.	Formulae		
22	w		.249
	1 + w		1.249
23	t		.20
	1 — t		.80
17	R	322 ÷ 100	3.22
15	V		21.0
16	$V_1 = V \div (1 + w)$	21 ÷ 1.249	16.8
	E.H.P.	15740 ÷ 4	3935
20	E.H.P. $= \rho V \div 326$ $\rho =$ E.H.P. $\times 326 \div V$	3935 × 326 ÷ 21	61,000
24	$T = \rho \div (1-t)$	61,000 ÷ .8	76,300
21	$H = TV_1 \div 326$	76,300 × 16.8 ÷ 326	3,935
	B	From Appendix II of Ref. 4 for disc area ratio 0.40	0.105
44	$C_A = R^2H \div BV_1^5$	$(3.22)^2$ 3935 ÷ .105 × $(16.8)^5$	0.2915
	C_o	From Appendix II of Ref. 4 with C_A as argument and at maximum efficiency (See Figure 4 of this paper.)	.0748
	Efficiency "open"	Ditto	0.628
	Pitch ratio	Ditto	0.8
	$C_o = (H \div BD^2V_1^3)$ $D = (H \div C_oBV_1^3)^{\frac{1}{2}}$	$[3935 \div .0748 \times .105\ (16.8)^3]^{\frac{1}{2}}$	10.2
	P (effective)	Pitch ratio being 0.8	8.21
	Nominal pitch	8.21 ÷ 1.02	8.05
	E.H.P. ÷ S.H.P. = propeller efficiency × hull efficiency = .628 × .8 × 1.249		.628
	S.H.P. = E.H.P. ÷ .628	15740 ÷ .628	23050



Determination of C_Q and Efficiency
Froude Method.

FIG. 4.

SOLUTION BY SCHAFFRAN METHOD.

Line No. Table I.			
22	w		.20
	(1—w)		.8
23	t		.20
	(1—t)		.8
18	n	322/60	5.37
15	v_m	21 × .515	10.72
16	$v_e = v_m (1-w)$	10.72 × 0.8	8.65
20	E.P.S. = W v_m ÷ 75 W = E.P.S. × 75 ÷ v_m	$\frac{(15740 \times 75)}{4} \div (10.72 \times .986)$	27930
24	$S = W \div (1-t)$	27930 ÷ .8	34930
39	$C_n = n (S)^{\frac{1}{2}} \div (v_e)^2$	5.37 $(34930)^{\frac{1}{2}} \div (8.65)^2$	13.41
37	C_s	From curves Figure 12, of Ref. 2, C_n and η_p max. being the arguments (See Figure 5 of this paper)	1.79
	a	Ditto	.90
	η_p max.	Ditto	.58
37	$C_s = n D \div v_e$ $D = C_s v_e \div n$	1.79 × 8.65 ÷ 5.37 (9′.47)	2.885
	$P = aD$	0.9 × 2.885 (8′.50)	2.6
41	C_{nm}	From Figure 14, $C_s = 2.885$ and a = 0.9 being arguments	3.71
41	$C_{nm} = n \sqrt[3]{M \div v_e^5}$ $M = (C_{nm})^3 v_e^5 \div n^3$	$(3.71)^3 (8.65)^5 \div (5.37)^3$	15960
19	W.P.S. = 2π n M ÷ 75	$2\pi \times 5.37 \times 15960 \div 75$	7060
	W.P.S. × 4	(27850 Br.)	28240
	$\eta = \eta_p \eta_t \eta_w$	.58 × 8 ÷ .8	0.58
	Check as follows:		
29	W.P.S. = E.P.S. ÷ .58	15995 ÷ .58 (27100 Br.)	27500

From Figure 12 of Reference 2

From Figure 14 of Reference 2

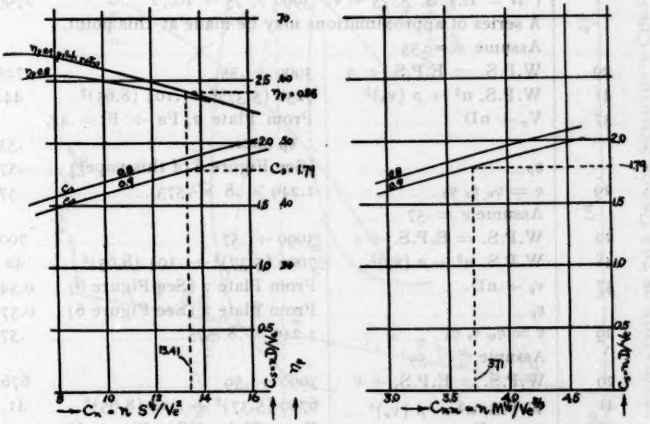


FIGURE 5.—ILLUSTRATION OF THE USE OF SCHAFFRAN'S CURVES.

SOLUTION BY SCHMIDT.

Line No. Table I	Formulae	
22	η_w	1.249
23	η_s	0.8
18	n	322 ÷ 60 — 5.37
15	v_s	21 × .515 — 10.72
16	$v_e = v_s + 1.249$	10.72 ÷ 1.249 — 8.65
20	E.P.S.	15740 ÷ 4 × .986 — 3990
20	E.P.S. $= Wv_s \div 75$ $W =$ E.P.S. $\times 75 \div v_s$	3990 × 75 ÷ 10.72 — 27995
	A series of approximations may be made at this point.	
	Assume $\eta = .55$	
29	W.P.S. $=$ E.P.S. $\div \eta$	3990 ÷ .55 — 7250
41	W.P.S. $n^2 \div \rho\ (v_e)^5$	7250 $(5.37)^2 \div .104\ (8.65)^2$ — 44.0
37	$V_e \div nD$	From Plate 2, Fa ÷ F = .42, η_p max. — .539
	η_p	(See Figure 6 of this paper) — .573
29	$\eta = \eta_w \eta_s \eta_p$	1.249 × .8 × .573 — .573
	Assume $\eta = .57$	
29	W.P.S. $=$ E.P.S. $\div \eta$	3990 ÷ .57 — 7000
41	W.P.S. $n^2 \div \rho\ (v_e)^5$	7000 $(5.37)^2 \div .104\ (8.65)^2$ — 42.5
37	$v_e \div nD$	From Plate 2 (See Figure 6) — 0.545
	η_p	From Plate 2 (See Figure 6) — 0.576
29	$\eta = \eta_w \eta_s \eta_p$	1.249 × .8 .575 — .576
	Assume $\eta = .59$	
29	W.P.S. $=$ E.P.S. $\div \eta$	3990 ÷ .59 — 6760
41	W.P.S. $n^2 \div \rho\ (v_e)^5$	6760 $(5.37)^2 \div .104\ (8.65)^2$ — 41.1
37	$v_e \div nD$	From Plate 2 (See Figure 6) — .55
	η_p	From Plate 2 (See Figure 6) — .58
29	$\eta = \eta_w \eta_s \eta_p$	1.249 × .8 .58 — .58
	Assume $\eta = .577$	
29	W.P.S. $=$ E.P.S. $\div \eta$	3990 ÷ .577 — 6910
41	W.P.S. $n^2 \div \rho\ (v_e)^5$	6910 $(5.37)^2 \div .104\ (8.65)^2$ — 42.0
37	$v_e \div nD$	From Plate 2 (See Figure 6) — .548
	η_p	— .577
	P ÷ D	— .87
29	$\eta = \eta_w \eta_s \eta_p$	1.249 × .8 × .577 (check) — .577
37	D $= v_e \div n \times$ coeff.	8.65 ÷ 5.37 × .548 = (9.64) — 2.94
	P = pitch ratio × D	2.94 × .87 (8′.4) — 2.56
	W.P.S. × 4	6910 × 4 (27250) — 27640

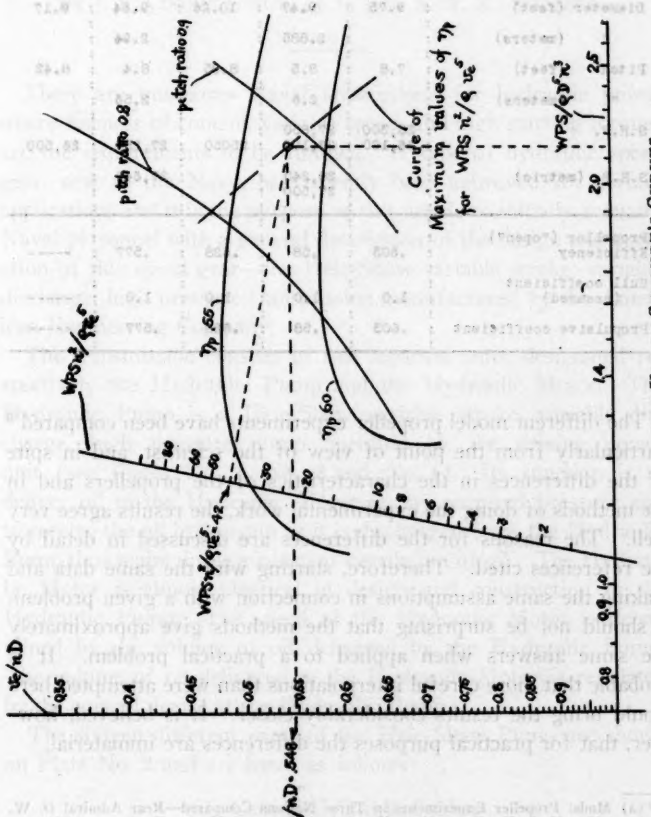


FIGURE 6.—ILLUSTRATION OF THE USE OF SCHMIDT'S CURVES.

Summary of Results.

	Taylor	Schaffran	Froude	Schmidt	Dyson
Diameter (feet)	9.75	9.47	10.26	9.64	9.17
" (meters)		2.885		2.94	
Pitch (feet)	7.8	8.5	8.05	8.4	8.42
" (meters)		2.6		2.56	
S.H.P.	25,300 26,100	27,850 27,100	25050	27,250	26,500
S.H.P. (metric)		28,240 27,500		27,640	
Propeller ("open") Efficiency	.603	.58	.628	.577	-----
Hull coefficient (assumed)	1.0	1.0	1.0	1.0	-----
Propulsive coefficient	.603	.58	.628	.577	-----

The different model propeller experiments have been compared [9] particularly from the point of view of the scientist, and in spite of the differences in the characteristics of the propellers and in the methods of doing the experimental work, the results agree very well. The reasons for the differences are discussed in detail by the references cited. Therefore, starting with the same data and making the same assumptions in connection with a given problem, it should not be surprising that the methods give approximately the same answers when applied to a practical problem. It is probable that more careful interpolations than were attempted here would bring the results considerably closer. It is believed, however, that for practical purposes the differences are immaterial.

[9] (a) Model Propeller Experiments in Three Nations Compared—Rear Admiral D. W. Taylor (CC), U. S. N., Proceedings Naval Architects and Marine Engineers, 1924.
(b) A Comparison of the Taylor and Berlin Experiments on Three Bladed Model Propellers—Dr. Ing. K. Schaffran—Schiffbau, April 22, 1925; abstract translation in Marine Engineering and Shipping Age, Oct., 1925.

THE HELE-SHAW HYDRAULIC TRANSMISSION.

By J. F. Cooke, Lieut. (J. G.) U. S. N. R., Member.

There are numerous Naval applications for hydraulic power where fineness of control, variable speed, and high starting torques are the requirements to be fulfilled. A type of hydraulic speed gear, new to the Navy, has recently been approved for certain applications and it is the purpose of this article to initially acquaint Naval personnel with a general description of the design and operation of this speed gear—the Hele-Shaw variable stroke, variable discharge, high pressure transmission manufactured by the American Engineering Company.

The transmission consists of two separate units, designated respectively the Hydraulic Pump and the Hydraulic Motor. The Hydraulic Pump is a Hele-Shaw variable stroke, variable discharge, high pressure pump operated by the driving power unit (see Plates No. 1, No. 3 and No. 4). Its function is to deliver oil to the Hydraulic Motor at any required pressure and to receive the oil back again as it is discharged from the Hydraulic Pump thus maintaining a constant circulation of oil. The Hydraulic Motor is almost identical in design and construction to the Hydraulic Pump. The speed of the Hydraulic Motor is determined by the volume of oil delivered by the Hydraulic Pump. The volume of oil delivered to the Hydraulic Motor is regulated by the control device at the Hydraulic Pump.

The sixteen different parts of the Hele-Shaw Pump are shown on Plate No. 2 and are listed as follows:

1. Central Cylindrical valve
2. Valve washer
3. Cylinder body
4. Spindle
5. Spindle nut
6. Cylinder body bearings

7. Plungers
8. Slippers
9. Floating ring
10. Floating ring bearings
11. Guide blocks
12. Guide rods
13. Cross head
14. Pipe cover
15. Shaft cover
16. Case

The Cylinder Body (3) and the Central Cylindrical Valve (1) might well be termed the " heart of the Hele-Shaw pump." (See Plate No. 3.) The Cylinder Body consists of radial cylinders, dis-

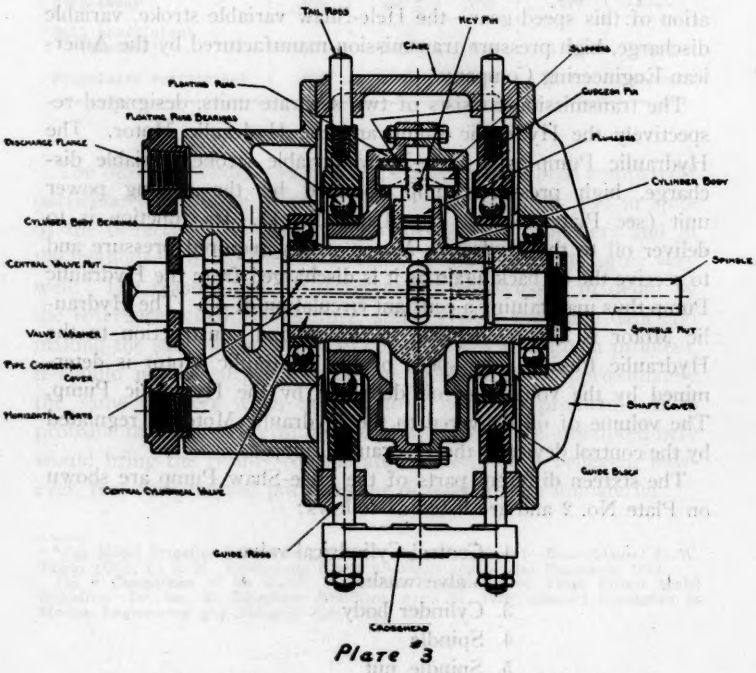


PLATE NO. 3—HORIZONTAL SECTION THROUGH "HELE-SHAW" HYDRAULIC PUMP.

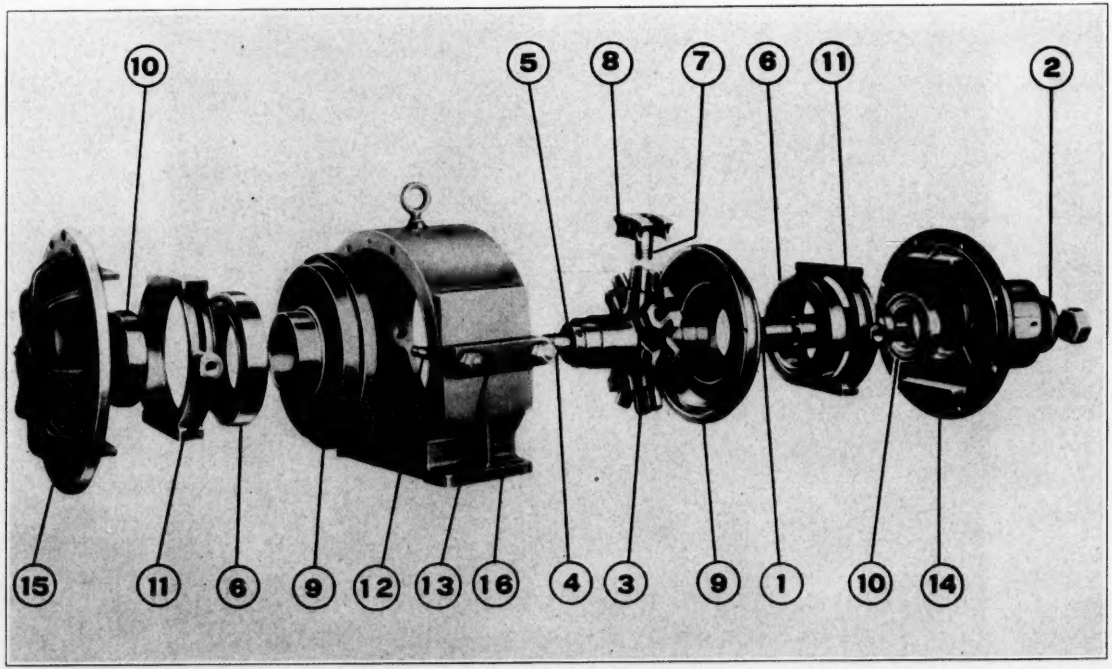


PLATE NO. 1—EXPLODED VIEW—"HELE-SHAW" HYDRAULIC PUMP.

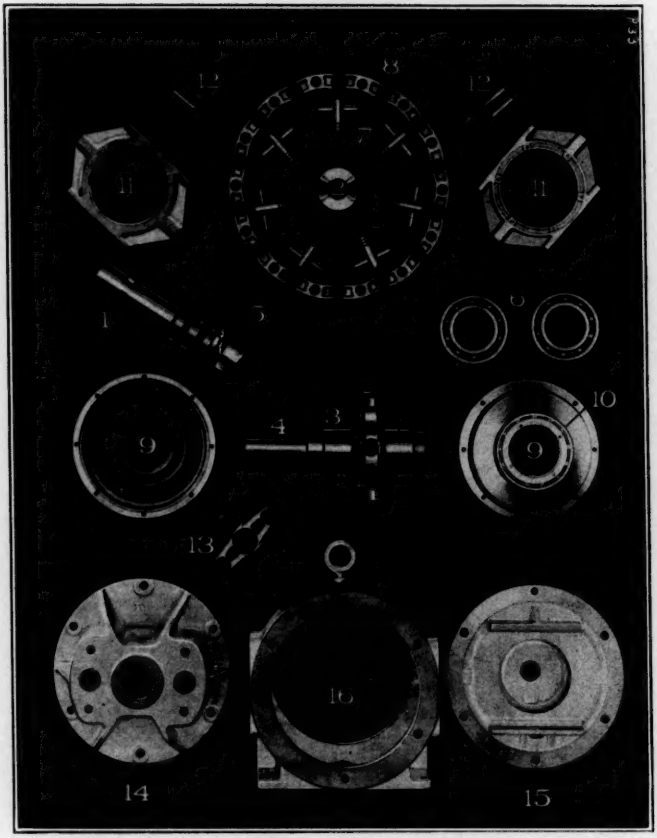


PLATE NO. 2—"HELE-SHAW" HYDRAULIC PUMP PARTS.

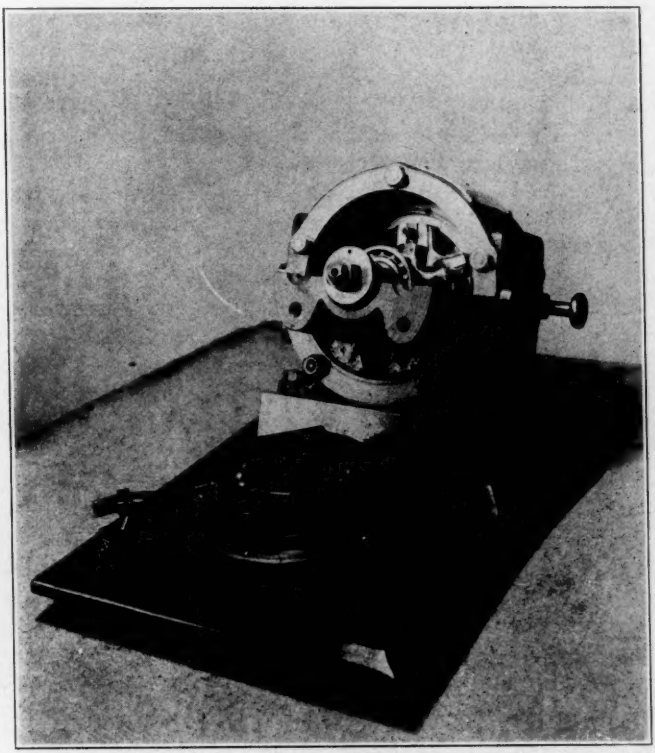


PLATE NO. 4—INTERIOR VIEW, "HELE-SHAW" HYDRAULIC PUMP THROUGH PIPE CONNECTION COVER.

charging at a common central port, mounted on ball bearings (6) seated in the covers of the pump. The number and size of these radial cylinders vary with the capacity of the pump. The Spindle (4), which is rotated by the prime mover, is secured to one end of the Cylinder Body (3) and extends out through the Shaft Cover (15).

The Central Cylindrical Valve (1) is a shaft having two horizontal ports running through it parallel to its axis, and is fixed in the Pipe Cover (14) directly opposite the Shaft Cover (15). This Valve does not rotate. The Cylinder Body (3) rotates about the Central Cylindrical Valve (1) carried by the two Cylinder Body Bearings (6). The clearance between the Cylinder Body (3) and Central Valve (1) is sufficient to allow a film of oil to pass between the two surfaces, therefore preventing any rubbing friction. The two horizontal ports in the Central Cylindrical Valve (1) are plugged at the inboard end and discharge into the Pipe Cover (14). The horizontal ports open into small chambers which coincide with the inboard ends of the radial cylinders. (See Plate 3.) As the Cylinder Body (3) rotates about the Central Cylindrical Valve (1), these two ports are in communication with the cylinders that happen to be on that side of the valve at the moment. The oil is drawn through one of these ports into the pump and discharged through the other, the direction of flow depending upon the eccentricity of the Floating Ring (9) and the Cylinder Body (3).

Each radial cylinder contains a Plunger (7) secured to Slippers (8) on each side of the plunger by a gudgeon pin. The Slippers (8) are set in a circular groove, one in each half of a Floating Ring (9) which completely surrounds the Cylinder Body (3). The Floating Ring (9) is mounted on each end of the pump. The Floating Ring (9) and Guide Block (11) assembly is supported on guides cast integral with the Pipe Cover (14) and Shaft Cover (15). This arrangement allows the Floating Ring (9) having the circular groove, in which the slippers are engaged, to be moved at will, so that the Floating Ring (9) is either concentric with the Cylinder Body (3) or is eccentric on either side.

As long as the Floating Ring (9) is maintained in a concentric position relative to the Cylinder Body (3), which is being rotated

about the Central Cylindrical Valve (1), no pumping action takes place as no relative reciprocating motion is given to the plungers and the pump is said to be in its neutral position. Immediately upon moving the Guide Rods (12), either in one direction or the other, stroke is given to the pump, the Floating Ring (9) becomes eccentric with the Cylinder Body (3) and due to this eccentricity the Plungers (7) are given a relative reciprocating motion, thus causing a discharge of oil through one of the horizontal ports in the Central Cylindrical Valve (1), and a suction of oil through the other horizontal port.

The Cylinder Body (3) is rotated by the prime mover about the Central Cylindrical Valve (1) at a constant speed, the prime mover running in one direction only.

The direction and volume of discharge depends entirely upon the relative position of the Floating Ring (9), and the Cylinder Body (3). The finest variation of discharge from zero to the maximum can be obtained and the Floating Ring (9) can be shifted so rapidly that the discharge of the pump can be reversed from the maximum in one direction to the maximum in the opposite direction in less than one second.

The construction of the Hydraulic Motor of the Hele-Shaw transmission is practically identically the same as the Hydraulic Pump with the major exception that the Floating Ring (9) is placed on maximum fixed eccentricity relative to the Cylinder Body (3). The parts of the Hydraulic Pump and the Hydraulic Motor are interchangeable.

There are many advantages to be gained by the use of an hydraulic transmission unit rather than a mechanical speed reducing unit among which are the following:

1. Infinite number of speeds between zero and a maximum in either direction of rotation.
2. Exceptionally sensitive control of speed.
3. Greater flexibility for meeting changing speed and torque requirements.
4. Smoother action as the result of the balancing of the pressure in the oil system with the resistance to be overcome.
5. Use of a constant speed prime mover, speed variations being provided by varying the stroke of the pump plungers.

6. Increased efficiency due to elimination of gearing.
7. Economy of power, due to the high efficiency of the system.
8. Utmost ease of operation.
9. Automatically self-lubricated by the oil used as the fluid in the system resulting in longer life and reduced maintenance.
10. Simplicity of electric control equipment.

The Hele-Shaw hydraulic pump and transmission is extremely simple in design and construction, rugged, easily serviced, highly efficient, and meets all the requirements of an hydraulic speed gear.

THE TREND OF NAVAL ENGINEERING.

Hydro-Carbon Gas Detectors, Commutator Resurfacers, Commutator Undercutters, Portable Air Dryers and Safety Glass.

By C. Huey, Civil Member.*

1. In the progressive evolution of Naval ships from sails to reciprocating engines, turbines or electric drive, from wood to steel hulls, from muzzle loading to breech loading guns, from oil lamps to electric lights, from hand operated to steam or electric pumps, from coal-fired to oil-fired boilers, from magnetic to gyro compasses—sufficient general information furnished by many able military and civilian writers associated with the operation or design, has accompanied the evolutions. The general trend of these prime factors is known to all interested readers.

2. However, there are many odds and ends of accessories or devices, not so well known, which have served to help in the evolution to higher efficiencies, quicker results, saving in time, or saving in man power. The scope of this article covers five selected items of general marine interest, which will be described and discussed in terms of their principal functions and trend in design.

HYDRO-CARBON GAS DETECTORS.

3. The increasing use of fuel oil for firing boilers or driving Diesel engines, has resulted in explosion hazards in the storing of the oil in compartments or tanks on shipboard. These hazards are especially potential when the storage places have been drained for cleaning, repairs, or alterations. The large volume of air which replaces the oil, in combination with very small percentages of volatile gases which are given off by hydro-carbon oils, sets the conditions for explosions in the presence of an igniting flame or spark.

4. It has been customary, before entering for inspection, to take samples of the average air in the oil compartments after steaming

* Material Engineer, U. S. Navy Yard, New York, N. Y.

and flooding. The older method of testing for explosibility was done by means of water displacement sampling cans, shown in Plate No. 1. These were lowered in the tanks through the manholes. The degree of explosiveness or the percentage of explosive gases in the cans, was then obtained by analysis in a chemical laboratory.

5. This method is obviously too delayed to serve the purpose. The present trend is to use an electrically operated, portable, self contained, hydro-carbon gas detector which indicates on a calibrated scale, the percentage explosibility of the heaviest of the hydro-carbon gases. For the lighter gases or mixtures, the indications are inaccurate, but on the side of safety. For known single gases, special scales or conversion charts are used to obtain more accurate findings.

6. The latest form of the above type for general use in Naval service, is shown in Plate No. 2. This is known as the Improved Burrell Gas Detector. The principle on which it operates is based on the loss in volume of a sealed sample, after the combustible gases are consumed by an electrically heated incandescent filament. The assembled outfit consists of the units necessary to reliably accomplish the above process. The sampling unit is a brass container fitted with a screwed top. This top contains the glower, a wired electric socket, and an air valve. Attached to the side of the container and cross connected to the bottom in the form of a U-tube, is a calibrated glass water column, open at the top to the atmosphere through a short rubber hose. The volume of the glass tube is designed to multiply the displacement in the container about 10 times, for close determinations.

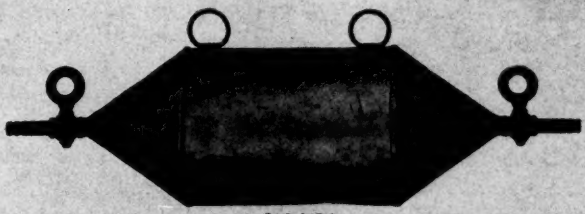
7. To operate the device, the assembled container is filled with pure water to the zero mark at the top of the scale. This results in a definite air space at the top of the container, which is the other leg of the U-tube. The assembly is carried into the suspected gas compartment, where the operator blows gently through the rubber hose until the water appears at the overflow at the top of the air valve. The operator then ceases blowing, and the water returning to the normal level, draws in through the air valve, a fixed volume of air (or gas). The air valve is then closed, and the device is removed from the compartment. The operator then, in an adjoin-

ing location in clear air, plugs in the glower circuit in the box containing dry batteries, the current from which is regulated for correct glower heat, by a series rheostat, to a set mark on an ammeter. In a short time, the combustible gas, if it exists in the container, is burned out of the sample. After cooling by agitation of the device, the water column is self-lowered in volume by the vacuum action in the container, to exactly balance the gas removed by combustion. The amount of change in water level of the glass tube is indicated by the calibrated scale in terms of per cent volume of the original sample.

8. Other forms of portable, electrically operated gas detectors, which are more complicated and higher priced, but which give *continuous* and instant indications, are at present limited to laboratory applications and on ships with trained operators. The principle under which these operate is based on the proportional increase in heat of combustion of flamable gas and air mixtures on the surface of a glowing non-catalytic filament. This physical effect is utilized by measuring the change in electrical resistance of a material possessing an appreciable temperature coefficient, assembled in an exploring cage in one type, or in another type, around which the gaseous air is aspirated. A fine platinum wire is usually used for the active material which is raised to a sensitive temperature by battery current. The change in electrical resistance is measured in terms of explosibility by means of a Wheatstone bridge scheme, in which the sensitive element is one leg, and a duplicate element sealed from gaseous atmosphere, for temperature compensation, is the opposite leg of the circuit. Excitation is furnished from batteries, and the unbalance or explosibility, is indicated on a calibrated meter.

COMMUTATOR RESURFACERS.

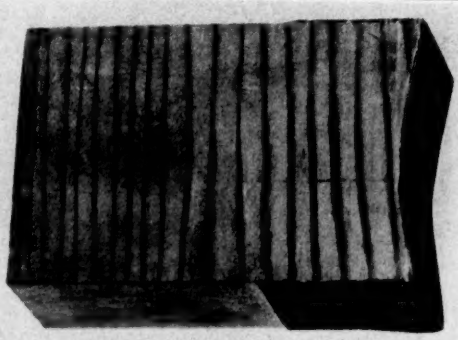
9. The extensive rise of direct current applications on shipboard has carried with it the problem of maintaining the smooth finish required for good operation of the copper commutators of motors and generators. Although the use of the proper grade of carbon brushes, and undercut mica, reduces the necessity of dressing the commutator except at rare intervals, there exists many instances where the service requires frequent applications of a



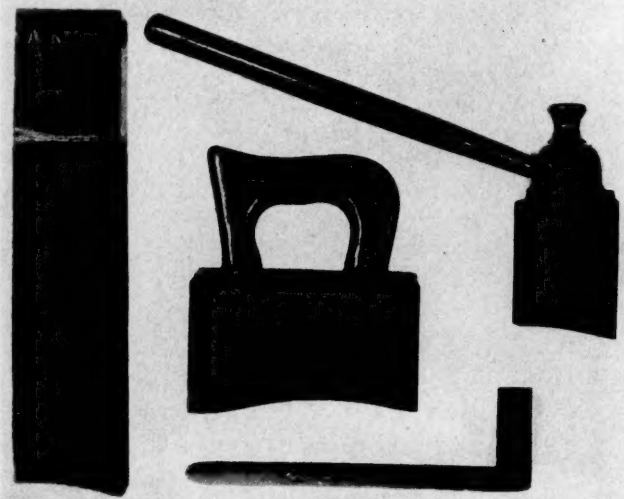
OLD WAY
PLATE 1.

NEW WAY
PLATE 2.

HYDROCARBON GAS DETECTOR

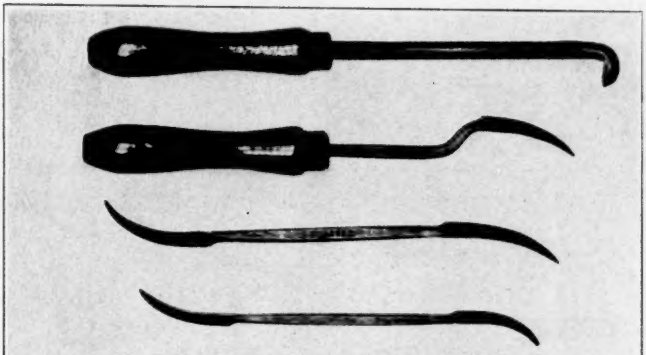


OLD WAY
PLATE 3.

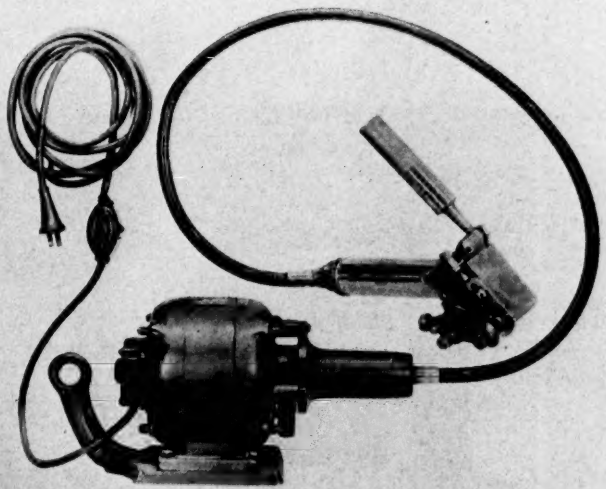


NEW WAY
PLATE 4.

COMMUTATOR RE-SURFACERS

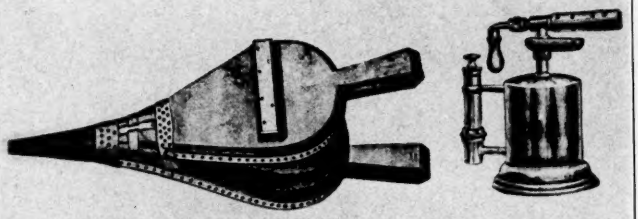


OLD WAY
PLATE 5.

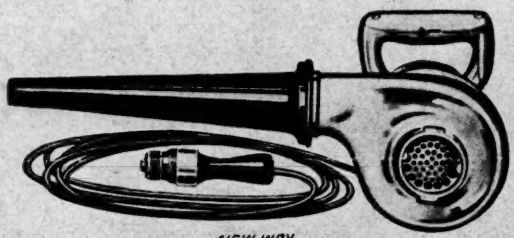


NEW WAY
PLATE 6.

COMMUTATOR UNDERCUTTERS

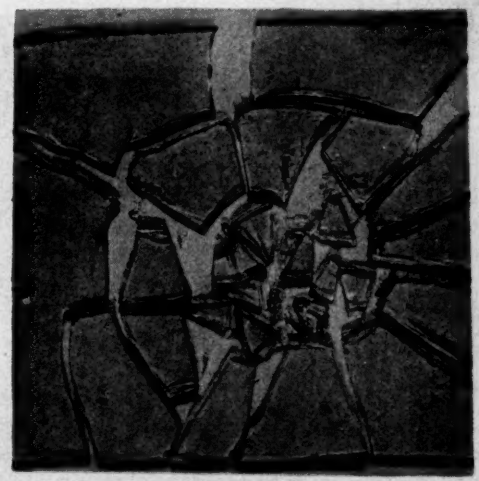


OLD WAY
PLATE 7.

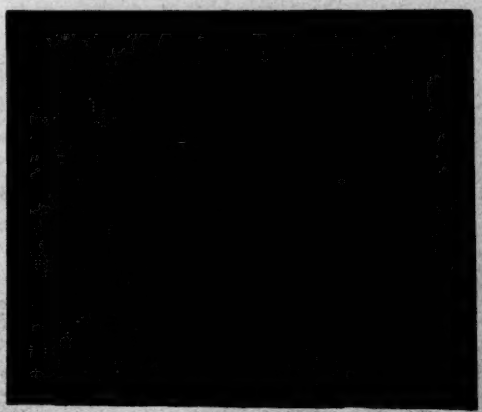


NEW WAY
PLATE 8.

PORTABLE AIR DRYERS



OLD WAY
PLATE 9.



NEW WAY
PLATE 10.
SAFETY GLASS

method to smooth out the burned spots, grooves, ridges, high bars or high mica, caused by improper materials, poor design or overheating.

10. The method used from the earliest days, was to hold a piece of sandpaper against the revolving commutator until the paper ceased to cut, and then to renew the same and repeat the operation until the surface reached the desired smoothness. This method was improved by securing the sandpaper on a curved block of wood (see Plate 3). These methods are not only dangerous to the operator, but result in unevenness. In addition, the sandpaper rapidly fills with copper and it cuts so slowly that extensive re-surfacing or smoothing becomes impracticable.

11. To improve the method, the accessory manufacturers have devised a synthetic, non-conducting, abrasive stone, which cuts fast and continuous, and which wears just fast enough to supply new cutting particles and to prevent clogging. These stones, which are 85 per cent efficient, that is, 85 parts of copper are removed with 15 parts of stone, are made in different grades of fineness and in various shapes and style handles, to meet every application with maximum safety (see Plate 4).

12. For more extensive operations, involving the removal of deep grooves, flat spots or large eccentricities, where removal of the armature to a lathe for truing with a steel tool is not practicable, and where it is desired to resurface under the machine's own power at normal speed which may be too fast for a steel tool, the stones are clamped in a special adjustable carriage supported by the brush arms or brush rigging. The grinding is then carried out by screw adjustments, across the active length of the commutator, in similar accurate manner as in feeding a steel tool in a lathe.

COMMUTATOR UNDERCUTTERS.

13. One of the important modern improvements in the successful operation of commutators of motors and generators is to undercut the mica insulation between the copper bars to a uniform depth of from 1/32 inch to 3/32 inch, depending on the size of commutator and thickness of insulation. Most manufacturers perform this work at the factory, but for the machines which are not

done, and to renew the undercutting, it is necessary to obtain and use practical tools.

14. The first undercutting, which was inaugurated only recently, was done by hand with the end of a hack saw blade ground in the form of a sharp hook. Further improvements were made in hand tools in the form of curved files as shown in Plate 5. These are made extremely hard and offer long life with fast cutting. They are properly tapered and curved, allowing for the rocking motion so desirable in this work. Other designs are in the form of straight three-sided files which allow them to be used on three edges. Special types are made which cut on the draw rather than on the push stroke. Another design is used in cleaning out slots after undercutting, slightly beveling the copper edges to remove burrs and removing any obstruction parts of mica.

15. The increase in the practice of undercutting has brought with it the demand for power driven tools. There are now available (see Plate 6) several well designed devices operated from a flexible shaft driven by a small motor, which undercut the mica to a pre-determined depth by means of a small circular saw or milling cutter, the contour of which is shaped to produce the proper cut, and the thickness being obtained by selecting stock cutters suitable for the slots of the particular commutator. These devices are fitted with a depth gauge and are provided with a micrometer screw for adjusting the depth of cut. Roller guides, "V" shaped, are also incorporated to guide the device from the adjoining cleared slot. By the use of these power devices, uniform slotting may be obtained at a great reduction in time and effort over the hand tools.

PORTABLE AIR DRYERS.

16. In all marine installations of electrical control and distribution panels, switchboards and protective boxes, condensed moisture has a great tendency to collect on the surfaces of the insulating parts. Under certain atmospheric conditions, this condition becomes so aggravated, and the insulation resistance of the various circuits to "ground" so reduced, that operation becomes hazardous. Break-down of equipment usually follows if the condition is allowed to persist.

17. In the earlier days, the moisture conditions were not only more severe due to water being trapped in the enclosing boxes by the use of long lines of metal pipe conduit, but the effects of the moisture on hygroscopic and un-impregnated insulations, was more persistent. In the absence of other practicable means, gasoline torches or hand bellows (see Plate 7), were used to alleviate the moisture conditions. As the drying of moisture is increased by both heat and volume of air, it is obvious that neither of the devices were efficient or speedy enough to clear up the numerous circuits involved.

18. In modern installation, even where pipe conduit is no longer being used, and where non-hygroscopic and impregnated insulations are being more fully realized, the surface leakage under marine conditions is severe enough to require modern high speed devices to raise the insulation between opposite polarities and between live parts and ground, to values above the minimum safe operating requirements. Such a device is shown on Plate 8. This consists of a portable, high velocity centrifugal blower of about 50 cubic feet per minute capacity at a velocity in the order of 200 miles per hour, driven by a fractional horsepower motor from lamp socket voltage. Heater coils are fitted in the intake side of the blower which are energized at will by a separate switch from the same line, so that warm air may be discharged through the insulated nozzle. The assembled device is light weight and convenient to apply to any wet electrical mechanism.

19. The device, with the heater turned off, can be used as a blower for removing dust and dirt from electrical or mechanical machinery. Due to the fact that the air is only slightly compressed to give mostly velocity pressures, the air delivery is free from the moisture which accompanies air obtained from compressor lines. Also, due to the short path of the air intake and discharge, there is a noticeable absence of rust, scales and oil which usually are prevalent on high pressure air lines sometimes used for cleaning.

SAFETY GLASS.

One of the few undiscovered materials required for the comfort or protection of mankind from physical forces is flexible or non-fragile glass. In the absence of such a material, a combina-

tion of two sheets of glass and a sheet of transparent nitro-cellulose bonded together with pressure and solvents, is being used in increasing amounts. This class of material is known as laminated or non-scatterable glass, sometimes erroneously called non-shatterable, or, non-breakable glass.

Plain glass, when struck with sufficient force with a hard object, or when stressed beyond its limit, instantly fractures from edge to edge, in lines radiating from the point of impact, or in patterns of intricate form, depending on the applied stress. In any case, a sheet of glass so broken results in loose pieces with many sharp cutting edges and pointed slivers (see Plate 9).

The purpose in fabricating non-scatterable glass, is, as the name implies, to prevent the glass when fractured, from scattering or displacing into loose pieces and slivers (see Plate 10). The glass itself, as used in present laminated glass production, has no special properties to resist fracture when over-stressed, for the reason that ordinary selected American made window glass is used for the purpose. The possible use of case-hardened glass, which recently has been perfected in small sizes for use in chipper's goggles and aviator's goggles, has not as yet been commercialized for sheets 12 × 20 inches, the standard window light size for the U. S. Navy. It is probable that the cost of lamination, plus case hardening, if accomplished, would make it prohibitive for use, considering the relative short useful life of laminated glass.

In the fabrication of laminated glass, the nitro-cellulose filler, also known as celluloid, pyralin, celenese or viscoloid, of .020 to .030 inch thick, on which is sprayed a solvent or a gelatin cement, is placed between chemically cleaned sheets of glass which in turn are sprayed with castor oil. The assembly is then forced into extreme physical contact, at high pressure and heat, by an air excluding process as accomplished by the use of the castor oil, or by a vacuum process as when using gelatin cements. The completed process, results in a solid, transparent, practically colorless sheet, which if fractured on either or both sides, has the properties of holding together all the pieces of glass by virtue of the bond between glass and the flexible nitro-cellulose.

The use of non-scatterable glass in Naval service, as now manufactured, is more or less limited, due to its comparatively short

life (about 18 months) under tropical sunshine, the effect of which is to chemically decompose the nitro-cellulose with resultant loosening of its bond with the glass. In this condition the sheet becomes stained, absorbs moisture, and the safety feature of its ability to hold the glass together when broken becomes nil.

The mechanical strength of non-scatterable glass in its ability to withstand breaking of the glass itself, is only about one-half that of plate-glass of equal total thickness. Non-scatterable glass, therefore, does not withstand gun-fire or blows from objects as well as plate glass, but due to its ability when properly fabricated and un-aged, to hold the fractured pieces together, its usefulness for wind-shields or window lights in navigating spaces and fighting tops, has been found to be warranted as a safety material.

Because of the comparative short life of the best commercial laminated glass, as evidenced by its discoloration, the hardening of the flexible filler or by the loosening of the bond, which latter deterioration is not always in evidence unless the glass is fractured, the trend at present is in the fabrication of a synthetic product of homogenous structure without the use of glass. Flexible, transparent materials which are non-fragile and non-inflammable, such as plastacele which is a cellulose acetate product, or polypas, which is a formaldehyde and urea condensation product, have shown very promising results but are in the early stages of development as regards size of sheets or thickness of same to the limit of satisfactory transparency. These synthetic products do not have the same degree of surface hardness as glass, but the non-fragility factor, for certain applications, is considered to be of sufficient importance to offset this deficiency. All known substitutes for glass exist only on the basis of being less fragile. However, the three incomparable qualities which are inherent in even the most ordinary clear glass, viz., surface hardness, stability and transparency, must needs be sacrificed to a more or less degree, in the substitution of any non-fragile material so far discovered.

DISCOVERED.

THE UNITED STATES NAVAL ENGINEERING EXPERIMENT STATION—ANNAPOLIS, MARYLAND.

LIEUTENANT CARL J. LAMB, U. S. N. R., MEMBER.

When the writer was a midshipman he knew there was an Engineering Experiment Station, because he could see it across the Severn from the Naval Academy. What it did, or why, was practically unknown to him and his fellows. Naval education has progressed naturally, in accord with the development of the profession and of engineering. The midshipmen of today not only see the Station across the river, but have instruction there. It is still a fact though, that too few people in the Navy and the Naval Reserve, let alone those people who should have a related interest because of the nature of their work in industrial and marine engineering, know that our Navy is operating quietly and without any fuss, but nevertheless efficiently and scientifically, a great engineering research laboratory whose work is almost daily producing engineering advance and progress, not only for the fighting ships, but for other Government departments, for the merchant marine and for manufacturers, oil refiners and industry in general.

In lieu of fifteen days' active training duty aboard a destroyer or light cruiser, the writer received orders to report at the Naval Academy this year, for the same period of duty at the Engineering Experiment Station, and not only enjoyed the duty immensely and learned much of engineering knowledge, but realized for the first time the ever increasing value of that Station and work it is doing. It is strongly felt that Reserve Officers as individuals and the service as a whole would benefit if it were considered routine training to regularly detail selected officers to the Station for periods of active duty.

Through the media of advertising, publicity releases and radio broadcasts, we have nearly all learned that great and spectacular accomplishments take place in the Bell Telephone Laboratories, "The House of Magic" at Schenectady, and the Research Labo-

ratories which carry on the great work started by Westinghouse. The Navy and its Engineering Experiment Station, on the other hand, do no advertising of any sort, and but for the outstanding work of such of its research men as O'Neil, Stuart, Lincoln and McAdam, the latter now with the Bureau of Standards, would hardly be known at all. The intent of this article is to give out a little information about the Station, its history and work, to the readers of the AMERICAN SOCIETY OF NAVAL ENGINEERS. The writer is, of course, indebted to the officers of the Station for a large part of the data contained herein, since two weeks did not allow sufficient time to gather such data from observation alone.

Previous to the establishment of the Engineering Experiment Station as such, that is from 1861 to 1876, tests were made of patented articles submitted for Naval use, when occasion offered, by boards of officers, appointed for that purpose. For a short period from 1876 on, Chief Engineer B. F. Isherwood, U. S. N., who was well known as an engineer and experimenter and after whom the engineering building at the Academy is named, was appointed senior member of a permanent Experimental Board, located at the New York Navy Yard. Later, when the needs of the Naval Service for engineers increased, the old practice was resumed of appointing boards as occasion required.

In 1895 Past Assistant Engineer F. C. Bieg, U. S. N., wrote an article which appeared in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS advocating an "Engineer Experimental Station and School" to serve the dual purpose of experimental research and engineering postgraduate work. For several years Engineer-in-Chief G. W. Melville, U. S. N., who was later to become famous as a co-inventor (with MacAlpine) of the Marine reduction gear for Naval and merchant ships, recommended to Congress the establishment of an experimental engineering laboratory. His efforts were only crowned with success after the war with Spain had caused the people to take a real interest in the Navy, and its vital importance to the nation as a necessary engineering and defensive organization.

In 1903 the Fifty-Seventh Congress passed an act which contained provision for the establishment of an "engineering experiment station and testing laboratory." The Station was completed and occupied in 1908, when its existence as an essential and active

adjunct to Naval and Marine engineering began, its official title being as given in the subject.

The Engineering Experiment Station is quite complete and has extensive facilities for the varied and interesting work which it performs. Even so, the quantity and scope of work done and contemplated is so great that extensive enlargement of plant and facilities has become necessary and is about to take place. In addition to office, storeroom and toolroom, the plant includes chemical and metallurgical laboratories, metals laboratory, machinery laboratory, instrument storage and calibration room, gasoline motor testing department, boiler house, power house, foundry, forge shop, sheet metal shop, machine shop, wood working shop and cafeteria. To the Station there are attached four motor launches and a fuel barge, besides several motor cars, and trucks. The boiler house is equipped to do test and experimental work upon all boiler fittings, attachments and auxiliaries as well as to generate steam by combustion of either oil or coal fuel. The power house contains steam geared turbine generators and Diesel generators, not only for generation of power flexibly, but to permit extended service tests of oils, packings and similar materials. Steam for various test purposes may be generated at pressures up to 500 pounds gage and at several hundred degrees superheat.

PERSONNEL.

The personnel of the Experiment Station is barely adequate for the work in hand and at present consists of the following:

The officer in charge, the present incumbent being Captain H. R. Greenlee, U. S. Navy, one of the experienced and well known engineers of the Navy.

An executive officer is in charge of tests, an engineer officer is in charge of the power plant, shop and stores, and three engineer postgraduate officers are in charge of the metals, chemical and mechanical laboratories, respectively.

There is one mechanical engineer, and an assistant for general machinery tests. Associated with them is an engineer for welding.

One chemist and one assistant chemist are responsible for analyses and examination of metals, compounds, oils, paints, fuels, etc.

One metallurgist and two assistants make investigations of endurance and chemical properties of metals.

A chief clerk, clerks, stenographers, librarian and messengers take care of the types of work indicated by their ratings, while the necessary laboratorians and laboratory helpers assist in test work as observers in the three main laboratories.

One foreman, one quarterman, one leadingman and one leader electrician supervise the work of the considerable force of machinists, pattern maker, molder, sheet metal worker, blacksmith, boiler maker, fireman, motor launch engineers, helpers and laborers; in all a total of about one hundred and twenty-five in number make up the Station complement. Men who have previously served in the Navy are preferred for employment at the Experiment Station because of their all around knowledge and familiarity with Naval service, engineering conditions and practice. Several of the civilian employees are in the Naval Reserve.

ACTIVITIES.

The Experiment Station is under the control of the Bureau of Engineering of the Navy Department. Test work can only be authorized by the Bureau, the costs being charged to the proper appropriation, or against a "special deposit" made by the manufacturer of the apparatus, equipment or material to be investigated. Since the Experiment Station is situated adjacent to the Naval Academy, the Superintendent of the Naval Academy also acts as the commandant of the Experiment Station. The value and variety of activities of the Experiment Station are considerably more numerous than the title "Experiment Station" would seem to indicate, and may be grouped as follows:

1. Testing.
2. Research.
3. Instruction.

} Covering all experimental work.

4. Increase, maintenance and improvement of equipment.
5. Repair and maintenance of station and power plant.

It is frequently difficult to distinguish clearly between testing, experimental and research work. All investigations of any type or classification are given a "test number," by which they are identified, while in progress, and referred to in reports records. Quite naturally any particular "test" may require that more than one of the various lines of investigation be undertaken, either in succession or in parallel, and very frequently such is the case.

"Testing" may be considered as undertaken for the following purposes:

(a) Examination for conformity with specifications,
(b) Examination for the framing of specifications,
(c) Performance and endurance of machinery,
(d) Performance and endurance of apparatus and accessories,
(e) Performance and composition of materials.

ILLUSTRATION No. 1

"Research" may be considered as applying where:

(a) Existing data is not systematic or sufficient,
(b) A new combination of mechanical principles is desired or proposed for a special purpose or need,
(c) A new combination of physical principles is desired or proposed for a special purpose or service,
(d) A new combination of mechanical and physical principles is desired or proposed for a special purpose,
(e) A new material or compound is to be developed for a special use.

ILLUSTRATION No. 2

Instruction at the Experimental Station, while not extensive, is given as follows:

All midshipmen are taken on inspection trips of the testing plant, and shown the equipment, demonstrations being made of such tests as may be underway or specially arranged, of test apparatus and of machinery in operation. In addition, lectures are given by the test officers, the mechanical engineer, the chemist and the metallurgist. For student officers of the post-graduate department at the Naval Academy, the instruction is practically the same as for midshipmen, but naturally more extensive. Instruction has also been given in photomicrography principles and practice upon occasion, to assist inspectors of engineering materials and to the officer in charge of the central tool plant at the Philadelphia Navy Yard, and one other Naval Reserve Officer has performed active duty at the Station.

The increase and improvement of equipment naturally involves a considerable amount of time and study in the examination of testing instruments or apparatus on the market, and in process of evolution, together with development and improvement of apparatus to meet the special needs of the Experiment Station. This latter is especially important because of the need for apparatus which will, as nearly as possible, duplicate actual operating conditions aboard the ships in the Navy. A large amount of the test procedure used and test machines in service have been developed specially for the purposes involved by the personnel of the Station. Proper mention should be made here of work done in which the Bureau of Engineering, while not responsible, is generally interested, the more important "tests" of this class being:

(a) Tests of materials for other Government Departments,

(b) Tests of aviation fuel pumps, oils and gasoline for the Bureau of Aeronautics, U. S. N.

(c) Examination and tests of materials as submitted by the U. S. Naval Academy High power radio station and by the Marine Barracks.

Late in 1919, all sound research and related investigation work of the Navy was transferred to the Station from the Submarine Base at New London, Conn. This important work was retained at the Station until 1923, when it was again transferred, including personnel, equipment and materials, to the Naval Research Laboratory at Bellevue, D. C. During the above period, the well-known Sonic Depth Finder and the Sonic Range Finder were developed at the Station. Both of these instruments are used for taking soundings at sea, and in July, 1923, such soundings of the Mediterranean Sea were taken from the U. S. S. *Stewart* by a representative of the Station. The officers of the *Stewart* then took soundings on the way out to Australia and the Far East, as previously described in the "Proceedings of the United States Institute" by Lieutenant Scott G. Lamb, U. S. N.

SCOPE OF WORK.

The Experiment Station had its inception as a working part of the Bureau of Engineering in August, 1908, so it has thus been in operation slightly over twenty-three years. As might be ex-

pected, the first few years of its existence were not too conspicuous for the amount of outstanding work done, since a considerable space of time was consumed in settling down, in adjustments, in developments of procedure, and of equipment. For several years, however, the Experiment Station has been turning out around 500 tests or more yearly. Probably the best numerical measure of the amount of work done may be expressed by stating that to date over 5500 tests have been undertaken and completed. It must be remembered, however, that many tests involve an amount of time and labor entirely disproportionate to that consumed by others.

It would not be practicable to cite all the tests that have been undertaken, and it is rather a difficult matter to group tests which cover the wide field represented, so it must be borne in mind that the following data is merely an attempt at a general summary, in which the nature of the work can hardly be more than indicated, and further that the items enumerated in the groups nearly all represent several "tests."

"Machinery tests" include turbines, blowers, turbine generators, rotary engines, rotary pumps, simplex reciprocating boiler feed pumps, condensate pumps, turbine driven centrifugal boiler feed pumps, air refrigerating machines, meters, gasifiers, Diesel engines, propeller lubricating oil pumps, centrifugal and rotary pumps, etc.

Under the "Heat Transmission Apparatus" are included condensers, air ejectors, evaporators, distillers, feed water heaters, oil heaters, air heaters, research work in heat transmission, investigation of boiler feed water treatment, condenser tubes and related research.

"Boiler Fittings and Accessories" include gage glasses, safety valves, water level indicators, boiler tube cleaners, soot blowers, gage glass frames, try cocks, bottom blow valves, pressure gages, pressure recorders, oil burners, baffles, "Electric-eye," smoke detector and similar equipment.

"Pump and Engine Fittings and Accessories," include pump-valve gear, feed water regulators, pump governors, pressure regulators, pump valves and valve seats, graphite lubricator, oil drips, grease cups, engine direction indicators, revolution counters, speed indicators, tachometers, carburetors, spark coils, gasoline shut-off, and various other such mechanisms.

The group " Valves, Piping, Fittings and Accessories" includes ordinary valves, reducing valves, steam traps, flange joint, armored steam hose, pipe unions, thread tight compound, pipe wrenches, insulation of steam piping through watertight bulkheads, heat insulating materials, aluminum heat insulating foil, together with such other items as may relate to valves, their fittings, connections and insulation.

With " Fuels" are included fuel oils, evaporative tests of coal, motor gasoline, aviation gasoline and furnace oils.

" Lubricants" include oil deposits, used oils, greases, ice machine, turbine, engine, dynamo, forced lubrication, steam cylinder for use with both saturated and superheated steam, gas engine and gas engine cylinder oils, graphite, graphite mixtures, aviation oils and the like.

" Packings and Gasket Materials" include sheet packings, for saturated and superheated steam, rod packings, piston packings, gage glass grommets, gas engine cylinder packing, slip joint packing plastic packings, metallic packings, boiler handhole and manhole gaskets, etc.

" Strength and Composition of Metals" include chemical analysis, strength and endurance, and structure as shown by photomicrography, bearing metals, boiler tube materials, valve materials for superheated steam, brasses and bronzes, cast irons and steels, alloys of steel with vanadium; chromium, nickel, monel metal, vanadium, condenser-tube materials; defective boiler headers, drums, nipples, furnaces and tubes; defective crankshaft and bolt material; fuse stock, galvanizing fluxes, gun jacket material, turbine blades, marine corps mess gear, or practically the whole range of metallurgy. Photomicrographic work is well developed and naturally occupies an important place in the investigation of metals. The technique of metal spraying is being investigated and developed, not only for spraying various metals upon parent metals, but upon non-metallic substances.

Under " Chemical Analyses" are included in addition to " metals," as stated above, boiler compounds, boiler waters, boiler deposits, scales, residues, turbine deposits and scales, gas engine muffler deposits, refrigerating brine solutes, etc. Mention should also be made here of tests of gas analysis apparatus and calori-

meters, hydro-carbons, compounds, gasoline dope, paints, varnishes, anti-rust compound, and the like.

"Miscellaneous Tests" cover a wide field and include gasoline drums, carbon remover, thermometers, ball and roller bearings, expansion screw sleeve, lock nut, lock anchor, paraffin illuminants, whistles, operated by air or steam, cotton tape, stuffing boxes, flexible coupling, temperature recorders, spark plugs, distant reading thermometers, Diesel engines, lubricating and fuel oil separators, including an oil separator for the prevention of harbor pollution, and many others.

"Miscellaneous Investigations" have included inquiry into water circulation in boilers, development of machines for testing engine oils, steam cylinder oils and gas engine cylinder oils; corrosion of boiler tubes and other materials; heat transmission between steam-water and steam air through metals; effects on the action of condensers by air leakage; temperature of inlet water and quantity of circulating water; radio equipment for aeroplanes; auxiliary emergency radio outfits; effects of moisture on rifled condenser tubing; effect of retarders in feed water heater tubes; zinc as a protective agent in boilers and condensers; steam whistles for tactical purposes; variation of specific heats of oils and brines with temperature; and many others. Only time will indicate how large this and the preceding group may eventually become.

Investigation, research and test is under way to further develop the electric and gas welding technique, particularly in view of the recent wide adoption of welded machinery for Naval work.

ACCOMPLISHMENTS—SOME EXAMPLES.

Since it is the writer's hope that through this paper the Experiment Station may become better known and more widely appreciated, space is taken to mention briefly a few of the most important accomplishments in the several classes of tests, although to do justice to each subject would require a separate article for each one, and many others not mentioned.

(a) Gage glasses have been thoroughly investigated, with the result that a type of gage glass, employing mica to insulate the glass from the action of steam, has been found, which will give

the desired safe service with a minimum of breakdown and attention.

(b) The tests of packings have extended over many years, but the work done has contributed largely to the reduction of the number of items on the schedules for packing requirements to a half-dozen classes of packing, all bids now being considered strictly in connection with the behavior of the corresponding packings in tests at the Experiment Station. The prices of packing have been materially reduced since such testing has been under way, and far better packing results are attained now for the various services involved.

(c) Lubricating oils are continuously undergoing investigation with a method of examination before use which indicates performance in service. Although little was known until only recently in this field, developments have been such that lubricating oils may be placed in the same relative status with packings. These investigations have led to the development and construction of oil testing machines of Experiment Station design (for the examination of engine and turbine oils) which have produced excellent results, fully demonstrated, and the all important "work factors" of lubricating oils have been developed, as recently described before the A. S. M. E. by Mr. O'Neil. Not only must lubricating oils meet certain minimum work factor requirements, but bids for lubricating oils are evaluated on the basis of the work factor of the oils. Designs are now under way on oil testing machines for the examination of steam cylinder and gas engine cylinder oils, so that work factors may be determined for this latter class of oils.

(d) The important question of corrosion of boiler materials has received a great deal of attention both as to the materials themselves and as to the treatment of boiler waters, with the result that there has been developed a boiler compound which, when properly used, aids greatly to prevent corrosion, although the main problem has not yet been solved. The Experiment Station also assisted materially in the development of a boiler water testing outfit as an instrument for use on board ship in connection with prevention of boiler corrosion.

(e) The practical application of photomicrography has progressed remarkably, so that reliable information may now be had

as to the probable cause of failures of used metals, and as to the probable performance of metals proposed for use, by examination of the grain structure and investigation as to proper heat treatment.

(f) Tests have even been made as to the relative evaporative efficiences of coal stored under salt water, under cover and in the open. Bunker coal taken from the old U.S.S. *Maine* was tested for evaporation efficiency after having been submerged in the tropical water of Havana Harbor for fourteen years.

(g) Apparatus and investigation involving heat transmission forms a considerable part of the testing work. While there are available at various places, of course, much available data on heat transmission, it is largely unrelated. Therefore, the Experiment Station has constructed apparatus for the investigation of heat transmission as between steam-water and steam-air, by means of which it is hoped to secure correlated data and to develop fundamental principles for the design and construction of all heat transmission apparatus manufactured or offered for use aboard Naval vessels. Along this same line considerable valuable work has been done with different types of condensers, and there are in hand investigations as to the effect of air leakage, temperature of inlet water, effect of air in circulating water and quantity of circulating water on condenser efficiency. Various tube materials have been under long-time test for several years.

(h) Boiler feed pumps of the simplex reciprocating and turbine driven centrifugal types have been tested in a variety of makes, with the result that no pumps for use on board ship are allowed to be installed unless long known as satisfactory in service, or reported as having passed satisfactory performance and endurance tests at the Experiment Station.

(i) Vane and propeller type turbine driven blowers for installation in cruisers and destroyers have been investigated at the Experiment Station, both with regard to the efficiency of the blower and of the turbine. A recent article written by Messrs. Lincoln and Treat and published in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, describes the tests and investigations into propeller type blowers which has resulted in the adoption of this type of blower for fire room forced draft aboard light cruisers, destroyers and battleships, and at the Fuel Oil Test Plant in Phila-

delphia Navy Yard. Such test work has necessitated the construction of a special blower test chamber and the adaption of a horizontal electric dynamometer for use in the vertical position. Recently a larger blower test chamber has been acquired and propeller blowers up to 150,000 cubic feet per minute capacity may now be tested.

(j) Numerous tests have been undertaken to determine the accuracy of water and oil metering devices for ship service, and the effect of continuous service on these devices has been learned. Before and after acceptance trials of new machinery aboard Naval vessels, it is routine practice to have all fuel, water and steam meters calibrated at the Station.

(k) Investigations of several types of fuel oil burners to discover effect of pressure and temperature of oil on the quantity discharged have been satisfactorily completed.

(l) Reducing valves, bottom blow valves, pump valves, and ordinary valves have been and are being subjected to thorough performance and endurance tests, to the end that only those which combine simplicity of design, sureness of operation and length of service may be accepted for use in the Navy.

(m) Safety valves likewise have been and are being so tested. The work done has had to do with capacity rating, lift of valve, design of springs, valve, and valve seats, and has resulted in the modification of specifications in several particulars, thus giving the Navy and the Merchant Marine safer and more simple valves for the extremely important use involved.

(n) Extremely important work has been done during the last four or five years in uncovering data concerning the strength of metals under cyclic stresses. In this research it has been demonstrated that the fatigue resistance of metals, when subjected to the combined action of stress and a medium such as water, is lowered in an extraordinary degree. This fact is of fundamental importance, and naturally has attracted international attention.

Among the important items recently completed, or which show promise of successful conclusion, while being of outstanding value, attention must be called to the work factor tests for oils, the corrosion fatigue limit tests for metals, the packing tests, the tests of furnace oil gasifiers, and the investigations of boiler feed water

treatment. Because of the probable use of alternating current turbine generators and electric motors aboard future Naval vessels, the Engineering Experimental Station is now faced with the prospect of having to provide alternating current power, starters and facilities for testing alternating current motor driven auxiliaries.

GENERAL REMARKS.

All "tests" are conducted from a "Service" point of view, as nearly as possible approaching those severe conditions encountered on board ship as the facilities of the Experiment Station will permit. Special effort is made to conduct endurance tests there, where practicable, frequently followed by service tests at sea.

Reports are written in a logical standard form, and embrace the general headings as illustrated. It is the general practice that all tests are considered to be investigations into the merits of the subject of test. Reports usually contain discussion, conclusions and constructive recommendations, which latter are worked out with a view to the probable improvement of the subject of test, especially where the object exhibited is reported upon as unsatisfactory as a whole, or in part.

Data covered in "Test" reports.

1. Origin of test—authority for test.
2. Subject of test—description of material or apparatus tested, including history, if any.
3. Purpose of test—specific lines of investigation to be followed.
4. Test apparatus—description of test apparatus and arrangements.
5. Manner of conducting test—observations taken, conditions maintained, etc.
6. Results of test—test data.
7. Discussion of results.
8. Conclusions.
9. Recommendations.
10. Exhibits, plates, charts and curves.

ILLUSTRATION No. 3.

All reports of "tests" are necessarily transmitted in triplicate to the Bureau of Engineering, which forwards a copy of the report to the contractor or exhibitor, if there be one. All exhibitors are prohibited from using these reports for advertising purposes, though they may and generally do, of course, make use of the report as they see fit for the constructive change and improvement of the product. Copies of reports on aviation materials are sent to the Bureau of Aeronautics. In those cases where materials for test are received from the various Inspectors of Engineering Materials, copies are sent to the Inspectors.

The results of the work done at the Experiment Station are little known, though a few reports are sent to some Naval Officers by the Bureau of Engineering. Occasionally write-ups of tests appear in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, the "Journal of the A. S. M. E.," etc., but there is at present no way of making known to many interested engineers in the service and the country at large the results of such investigations as might be of general interest and information, and which are not considered confidential. Some definite means should be had for this purpose, perhaps corresponding in character to the bulletins issued by the Bureau of Mines of the Department of the Interior and other Government bureaus, and by various State and college experiment stations. Copies of the monthly test reports, however, and a list of the tests assigned each month are sent to several points throughout the Naval Service.

The field of Naval and allied engineering research is extremely wide in extent and its problems are notedly varied in character, but are rapidly becoming of greater importance. It will be noticed from the above that although many important problems have been solved or are being worked on, many more have not yet been touched by the Experiment Station. It is sure, though, that much of value has been accomplished and it is to be expected beyond question that the Experiment Station will continue to grow in importance and increase in value, to the Navy in particular and to the engineering world in general. The importance of the Station and its work have been increased materially because of recent treaties placing limits upon displacements of various classes of vessels, and because of the rapid acceleration of engineering and

scientific progress. The Experiment Station has been well established and is now truly in a position to demonstrate its continuing usefulness; the work it is intended to perform will never be completed; there must always be progress; and it is the work of the Experiment Station to assist in determining in an accurate and constructive manner what is progress and what is not, and further to shape that progress within its natural scope.

NEW PATROL BOATS FOR THE U. S. COAST GUARD.

By Commander Harvey F. Johnson, U. S. C. G., Member.

During the years 1926 and 1927, thirty-three boats known as the 125-foot patrol boat class were built by the American Brown Boveri Electric Corporation, now known as the New York Shipbuilding Company, for the U. S. Coast Guard. These boats were all twin screw, each having two 150-horsepower Winton air injection, Diesel engines. The engines were non-reversing, reversing of the propellers being accomplished by means of a reverse gear attached to each engine.

At the time of the trials of these boats, they made about 11.5 knots. When used in law enforcement work, trailing smugglers outside the twelve-mile limit, they were very effective during the early days of their service. Later the resourcefulness of the smugglers led them to use boats of increased speeds which in time were improved to such an extent that some of them were able to outmaneuver these 125-foot Coast Guard patrol boats.

In 1930, the Coast Guard decided to get out a design for an improved type of patrol boat which not only had increased speed but at the same time the comfort and seaworthiness which had been embodied in the 125-foot patrol boats. A careful study of the problem was made and a series of model tests run to confirm the calculations made for the form of hull best suited for the speed and length chosen for the new patrol boats. As a result of this study the 165-foot patrol boat was developed.

The general characteristics of the new patrol boats are as follows:

Length overall, feet and inches	165	0
Length on designed L. W. L., feet and inches	160	9
Length between perpendiculars, feet and inches	160	0
Beam, molded at deck (maximum), feet and inches	25	3
Beam, molded at waterline (maximum), feet and inches	23	9
Depth, molded amidships, feet and inches	13	2

Draft, designed salt water, feet and inches	7 0½
Displacement on designed draft, salt water, tons	294
Block coefficient	.378
Midship coefficient	.659
Total fresh water tank capacity, gallons	3460
Drinking water tank capacity, gallons	1015
Fuel oil bunker capacity (95 per cent full), gallons	7690
Fuel oil gravity tank capacity, gallons	100
Main propelling machinery, Diesel engines; twin screws.	
Total shaft horsepower	1340
Speed on trial, knots	16

Bids for the construction of seven 165-foot patrol boats were solicited and the Bath Iron Works Corporation of Bath, Maine, was awarded the contract for building these boats. The contract was signed January 21, 1931, and the first boat was delivered on November 27, 1931. The rest of the boats are to be delivered at regular intervals until April 27, 1932, when the contract is to be completed.

GENERAL DESCRIPTION OF HULL AND EQUIPMENT.

In order to obtain the desired speed, the lines were made rather fine, the lower water lines being slightly hollow forward and almost straight aft, while the load water line forward was practically straight and showed a little fullness aft. The sections forward are of the modified "V" type, while those aft are the straight "V" type out to the point where the turn of bilge starts. This combination of sections and water lines gives buttocks with easy curves and no hollow spots forward, while aft of amidships they are practically straight in the underwater body with a tendency to curve upwards above the load water line due to the cruiser type of stern which was used.

In choosing the scantlings for these boats, it was desirable to make them as light as possible and still maintain ample strength to assure seaworthiness under all conditions of operation. As a means towards this end, the frames, deck beams and water tight bulkhead stiffeners were made of bulb angles. In order to maintain the shell plating consistent with the light bulb angles, the bottom and side plating was made 12.8 pounds for half the length amidships, reduced to 10.2 pounds at the ends and the keel plate

and sheer strake plating was made 17.9 pounds for half the length amidships, reducing to 15.3 pounds at ends in the keel plate and 12.8 pounds at ends in the sheer strake plating. The deck plating on the weather deck is in general 7.7 pounds with increased thickness in the stringer plates and doubling plates fitted in way of guns, ventilators, bitts, etc.

Ample water-tight subdivision has been provided by means of six water-tight bulkheads and two oil-tight bulkheads. All of these bulkheads extend from the keel to the weather deck. Two of the forward bulkheads and one of the after bulkheads are fitted with water-tight doors for access through the living spaces.

There are two decks on these boats, the main or weather deck and the berth deck. The weather deck, as stated above, is all steel plated and the berth deck is wood planked with steel bulb angles for deck beams. The wood deck extends throughout the berthing and messing spaces with the exception that in the galley Alumalum tile is laid on top of steel plates. The walking flats in the engine room are of corrugated aluminum alloy plates laid on steel foundation bars.

Below the berth deck the compartments are used as follows: from stem to frame 7, fore peak; frames 7-17, fore hold (commissary stores); frames 17-28, main hold (miscellaneous stores); frames 28-31, fresh water tank; frames 31-35, magazine; frames 35-37, fuel oil bunkers; frames 53-64, shaft alley.

Above the berth deck the compartments are: from stem to frame 7, paint stores and chain locker; frames 7-17, berthing space for 18 enlisted men; frames 17-28, berthing space for 5 chief petty officers and 15 enlisted men; frames 28-35, four staterooms for warrant officers with armory, medicine locker and safe in passageway between these staterooms; frames 35-37, fuel oil bunkers; frames 53-64, crew's mess space, galley, ship's refrigerators and heating boiler; frames 64-69, officers' mess room and ship's office; frame 69 to stern, drinking water tank, hawser stowage space and rudder tillers and their connecting links.

On the main or weather deck, the deck house is constructed just forward of the trunk over the engineroom. The anchor windlass, one 3-inch, 23-caliber, anti-aircraft gun, two one-pounder guns, and two companion hatches for access to crew's quarters are

all located on this deck forward of the deck house. Aft of the deck house are located the hatch over the engineroom, two 19-foot dories on the port side, two 19-foot 4-inch surfboats on the starboard side, life-belt lockers, vegetable lockers, a hatch over the heating boiler and two companion hatches for access to the galley, crew's mess room, officers' mess room and ship's office.

The bridge is located at the forward end of the deck house and is raised about three feet above the main deck in order to assure a clear vision forward over the bow and aft of the top of the deck house abaft the bridge.

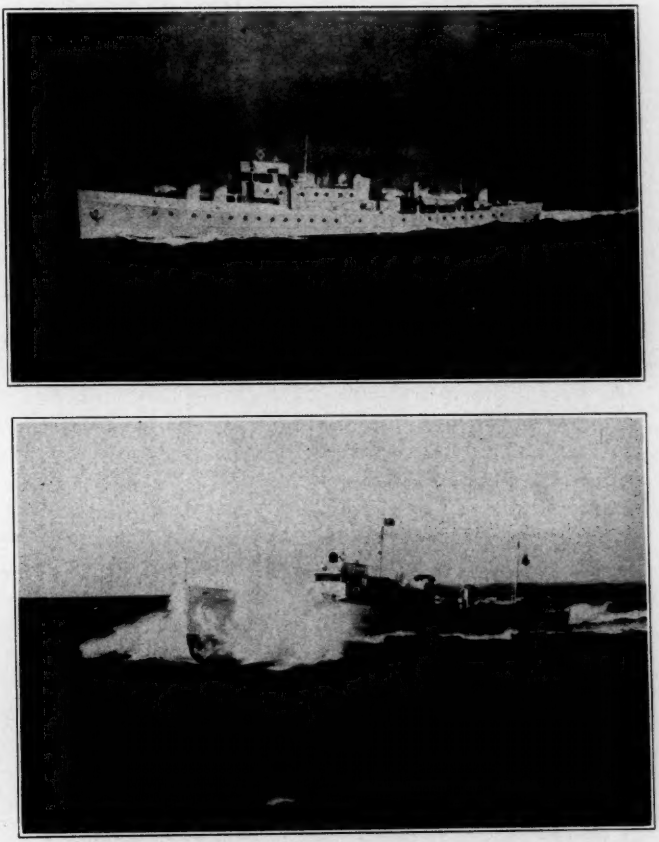
In the deck house are the commanding officer's stateroom, just abaft the bridge; the radio room; officers' washroom, shower and toilet spaces; crew's wash room, shower and toilet spaces, and means of access to the berth deck forward, to the warrant officers' staterooms and to the engineroom.

On top of the deck house are two 18-inch incandescent searchlights and one 18-inch high intensity searchlight, all manufactured by the Sperry Gyroscope Company. The radio direction finder loop, standard compass, flag lockers, two ventilation blowers and two life rafts are also located on top of the deck house.

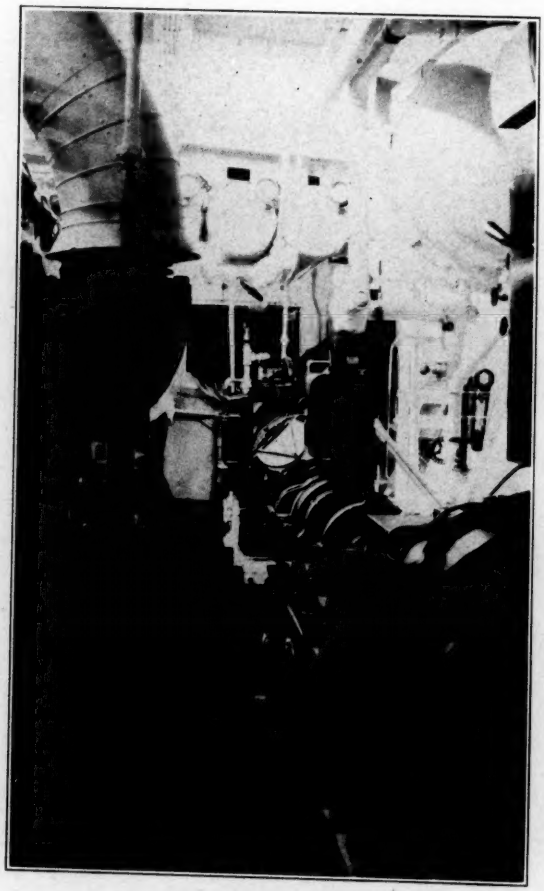
The heating system consists of a cast-iron, low pressure, steam-heating boiler and copper-fin type, extended-surface, radiators. The heating boiler was furnished by the American Radiator Company and is equipped with an Enterprise oil burner. The radiators were furnished by the McQuay Radiator Corporation and are installed in all the staterooms, berthing spaces, messing spaces, engineroom, bridge, radio room and toilet spaces.

Ventilation throughout the staterooms, berthing spaces and messing spaces is provided by three "Sirocco" utility blowers furnished by the American Blower Corporation. Two of these blowers are located forward on top of the deck house and one is aft on top of the hatch over the heating boiler. These blowers are motor driven and each one delivers 1200 cubic feet of air per minute.

The refrigerating plant consists of two Westinghouse electric refrigerators, one having a food storage capacity of 17 cubic feet and the other 10 cubic feet. These refrigerators are independent units, each having its own compressor, cooling coils, and expan-

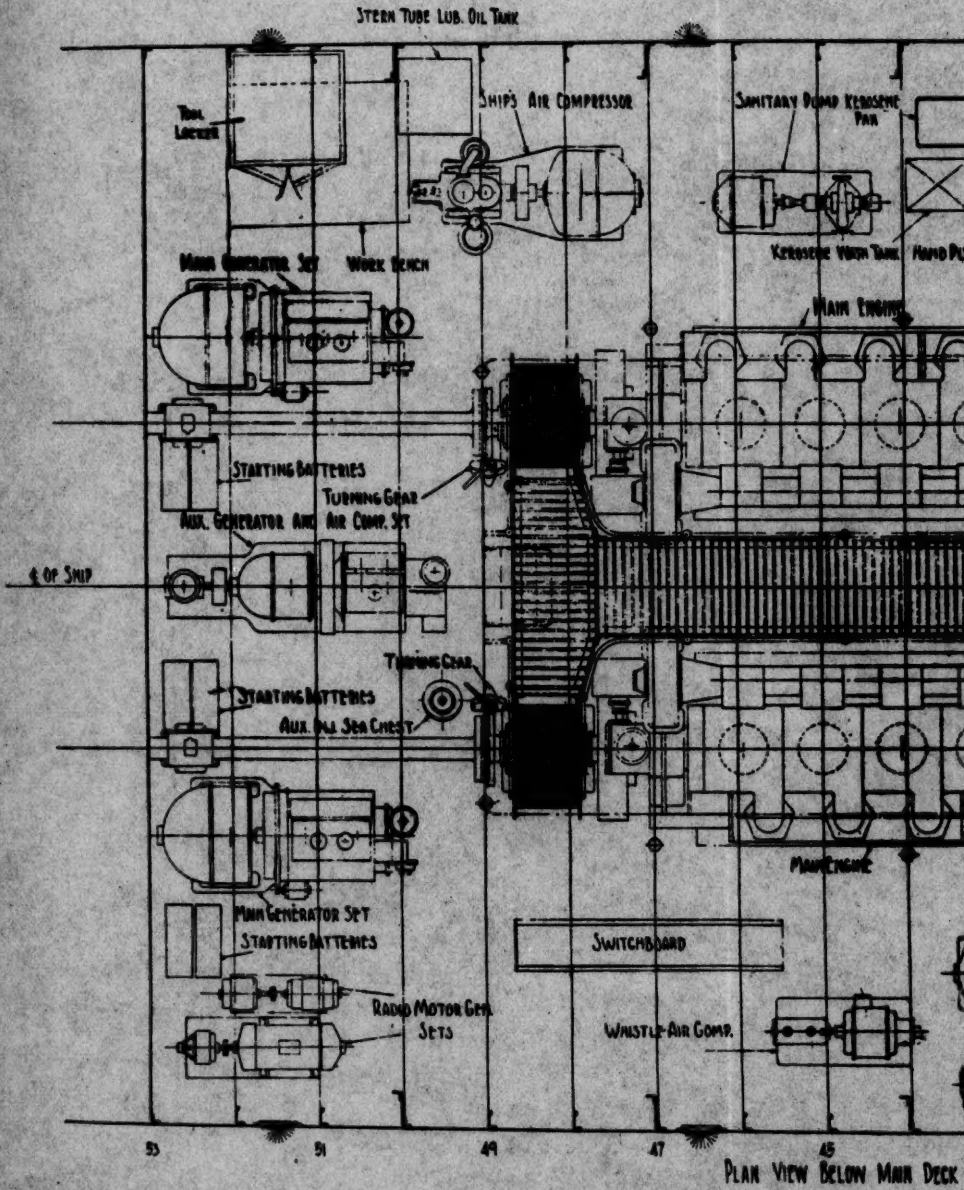


VIEWS OF "THETIS" UNDER WAY.

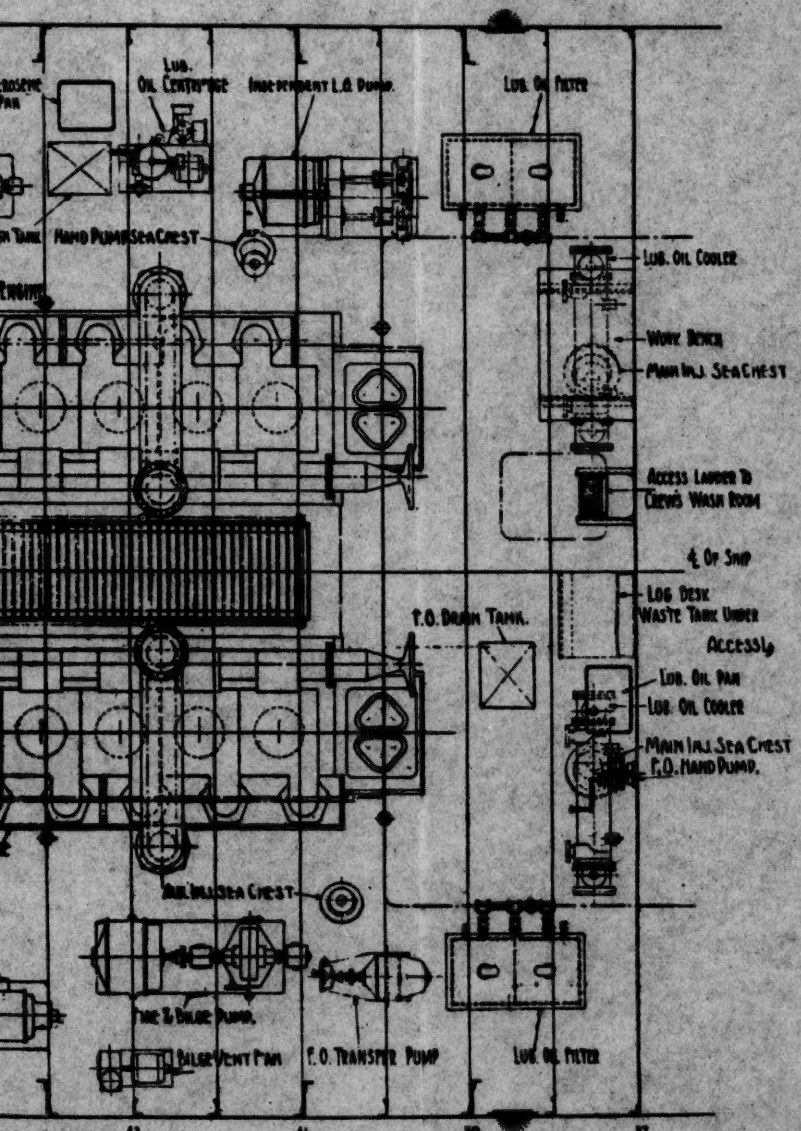


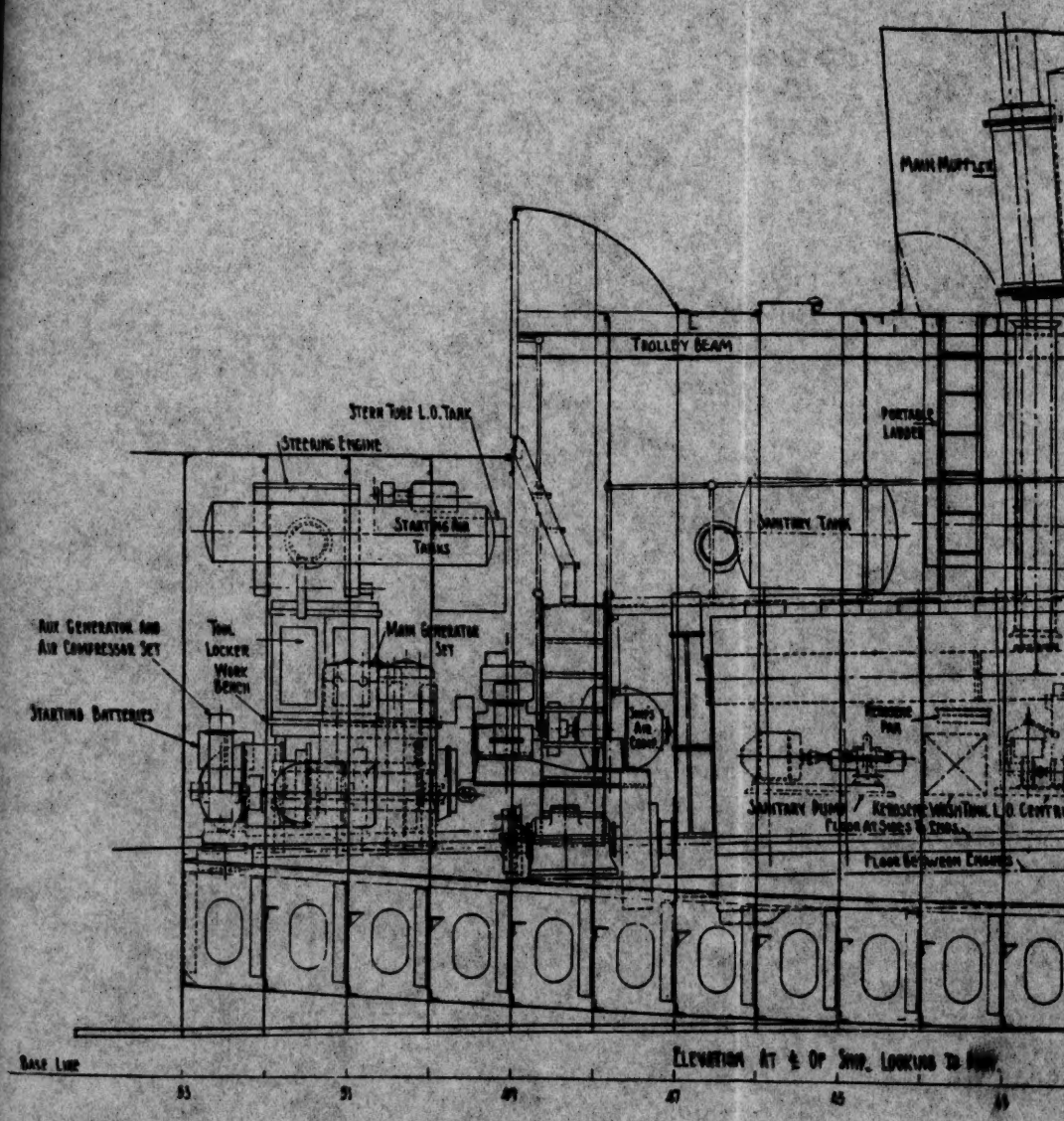
"THETIS" PORT SIDE ENGINE ROOM LOOKING AFT.

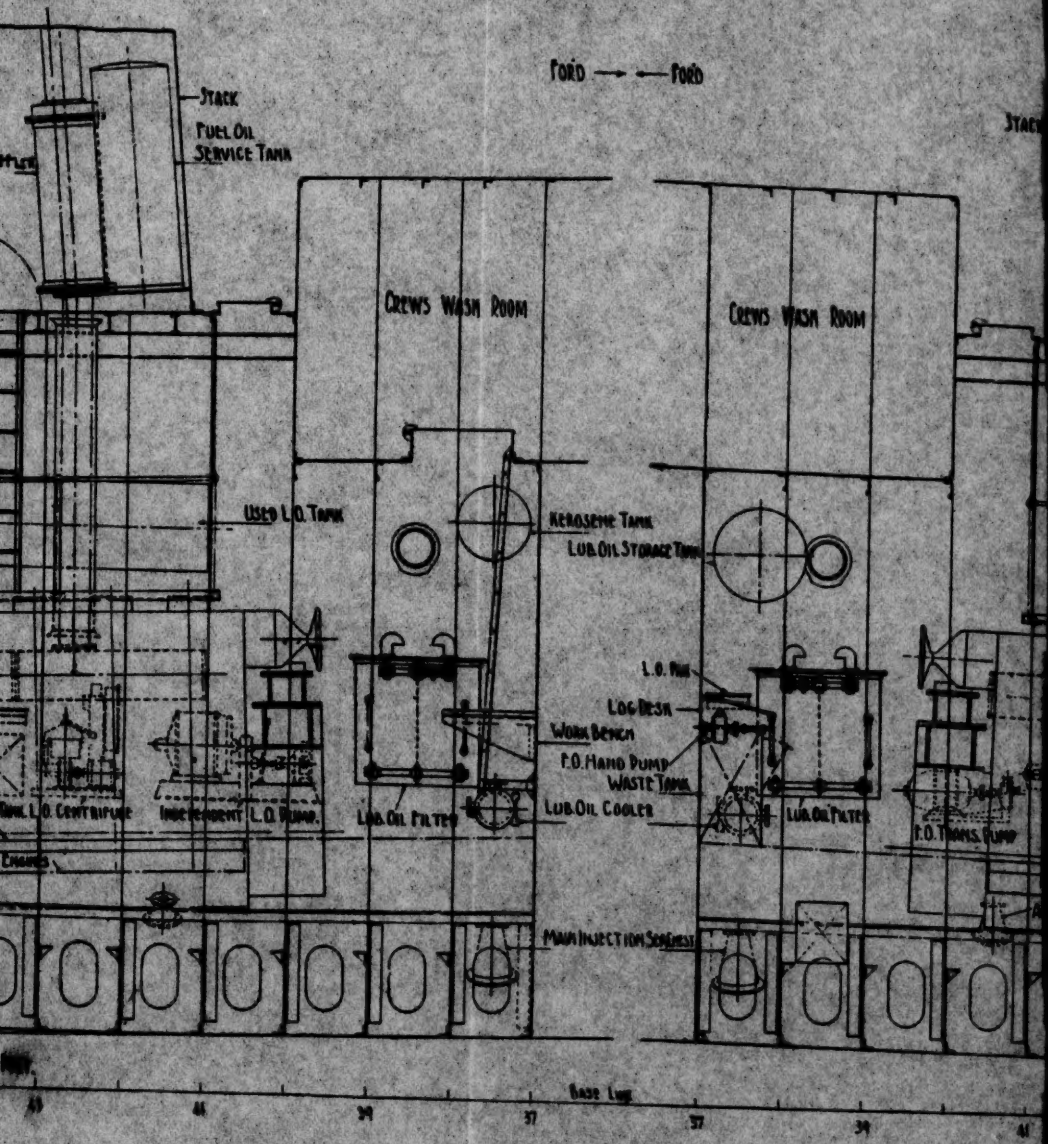
"THETIS" ENGINE ROOM LOOKING AFT.



Plan View Below Main Deck


Lub. Oil Centrifuge
Independent L.O. Pump.
Lub. Oil Filter
Hand Pump Sea Chest
Lub. Oil Cooler
Work Bench
Main Inj. Sea Chest
Access Ladder To Crews Wash Room
½ Of Ship
Log Desk
Waste Tank Under
Access Ladder
F.O. Drain Tank.
Lub. Oil Pan
Lub. Oil Cooler
Main Inj. Sea Chest
F.O. Hand Pump.
Fire & Bilge Pump.
Bilge Vent Fan
F.O. Transfer Pump
Lub. Oil Filter
43
41
39
37
Main Deck


Main Muffler
Trolley Beam
Stern Tube L.O. Tank
Steering Engine
Portable Ladder
Starting Air Tanks
Sanitary Tank
Aux Generator and Air Compressor Set
Tool Locker Work Bench
Main Generator Set
Starting Batteries
Sanitary Pump
Floor at Sides & Ends
Floor between Engines
Base Line
Elevation at ℄ of Ship, Looking to Port
53
51
49
47
45
43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L.O. PUMP
LOG DESK
WORK BENCH
F.O. HAND PUMP
WASTE TANK
LUB. OIL COOLER
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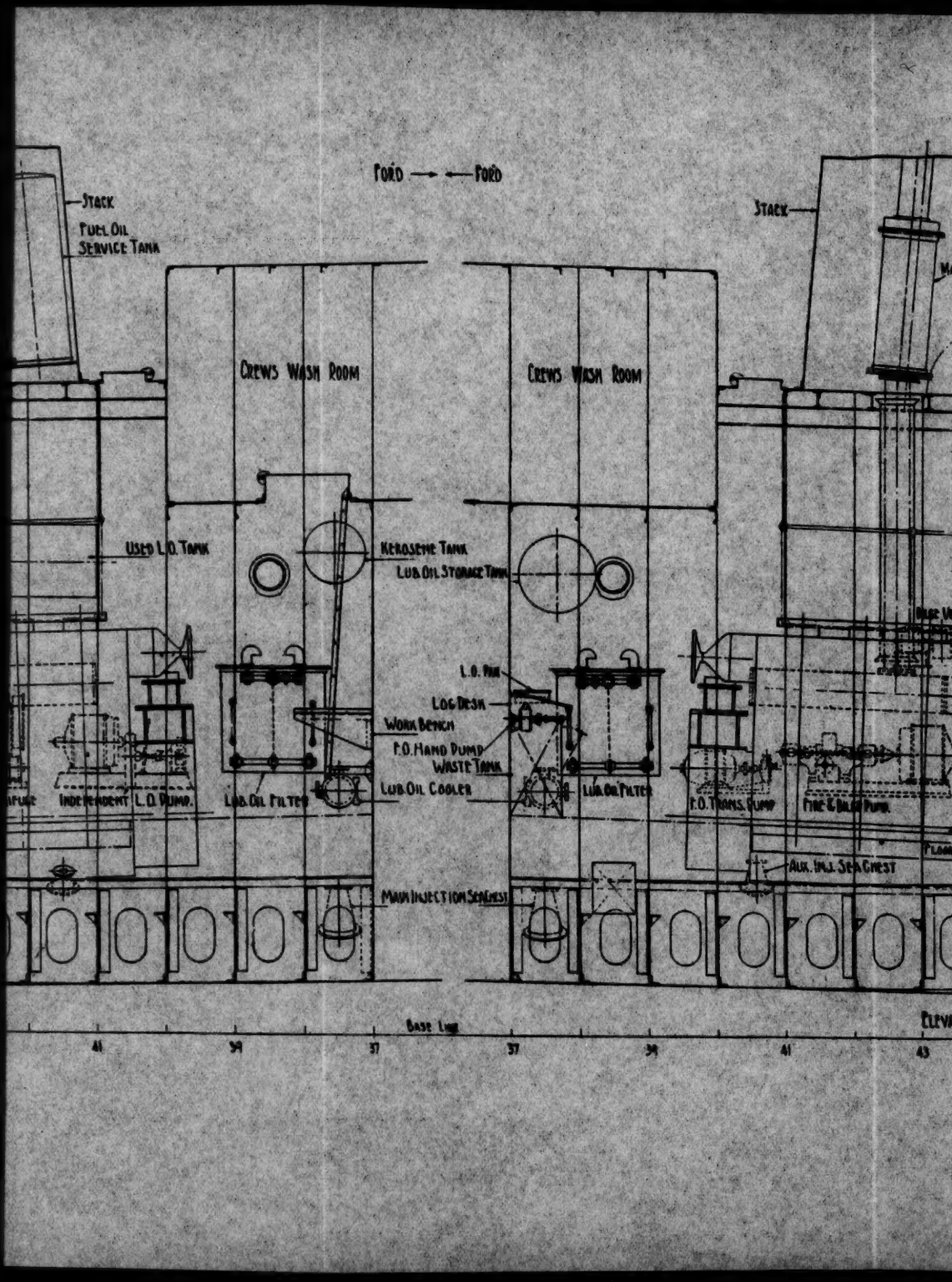
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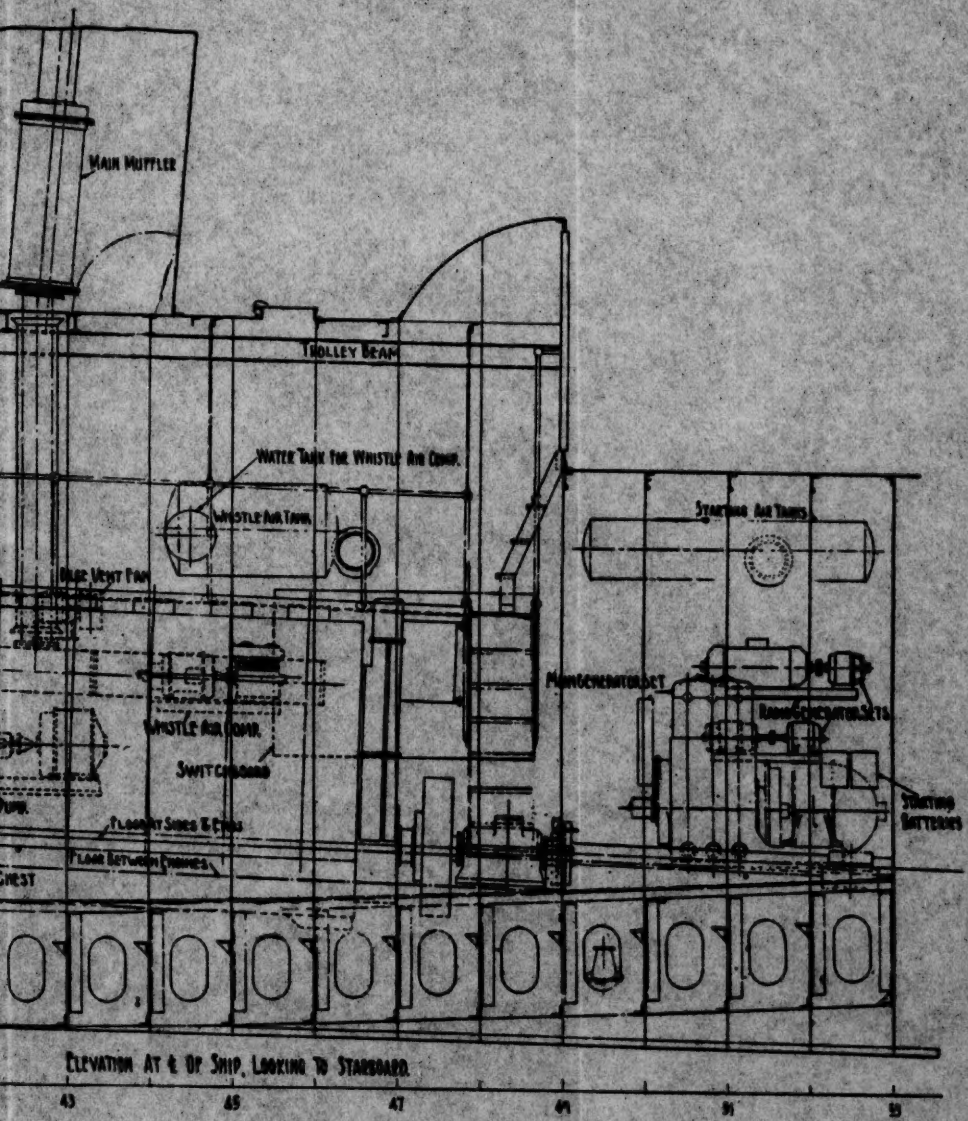


ELEVATION AT ℄ OF SHIP, LOOKING TO STARBOARD.

sion chamber. The machinery is all hermetically sealed with all joints in piping silver soldered or brazed, thereby reducing to a minimum the possibility of any leakage of gas occurring which might reduce the efficiency of the refrigerating unit or escape into the living spaces causing inconvenience to the officers and men in these spaces. As the refrigerating machines are all driven by alternating current motors, it was necessary to provide rotary converters to convert the ship's direct current supply to alternating current for each refrigerator.

The anchor windlass was furnished by the Hyde Windlass Company. The windlass is driven by a 7½-horsepower motor through suitable spur gears. The motor was furnished by the General Electric Company. The anchor windlass is designed to be able to lift a 900-pound anchor and 45 fathoms of ⅞-inch anchor chain at the rate of six fathoms per minute.

The steering gear was furnished by the Sperry Gyroscope Company. It is a unique combination of electric gear drive for power steering and straight geared drive for hand steering. The steering wheel in the bridge controls the motor contactors located in the engineroom and is also arranged so that it will also turn the drum driving the tiller ropes by means of a suitable train of gears when hand steering is used. The change from power steering to hand steering is made automatically when the power supply to the steering gear motor is shut off. During the trial trip of the *Thetis*, the first of these new patrol boats to be completed, it was found that for angles of helm up to about 10 degrees it was difficult for the wheelman to determine whether the steering gear was operating by power or by hand when running at full speed.

In the average twin screw boat fitted with twin rudders such as these boats are, the hull appendages are a source of appreciable power loss. In addition to the rudder abaft each wheel, it is customary to support the propeller by a shaft strut just forward of the propeller and in boats with fine lines such as these boats have, it is necessary to provide an additional shaft strut to support the shaft in between the after strut and the stern bearing in the hull. This intermediate strut is inevitable in this type of hull, as the shaft must be supported by bearings which are close enough together to prevent the shaft from sagging between bearings under

its own weight. The shaft strut which is normally installed just forward of each propeller is a source of considerable loss for it not only has more resistance than the intermediate strut due to its greater length but, being just forward of the propeller, it causes interference with the streamlines of the water flowing into the propeller. In the new Coast Guard patrol boats, the effect of this strut was eliminated by supporting each propeller by a bearing aft of the propeller. This bearing is located in a boss on the forward side of the rudder post. The rudder posts are in duplicate and together with the rudders form a streamlined section aft of each propeller. In this way an arrangement has been obtained in which the rudder and after strut are combined in one unit instead of two and the objectionable features of the after strut have been eliminated entirely. The trials of the *Thetis* confirmed the belief that this method of supporting the propeller would not introduce any more vibration than would the conventional strut just forward of the propeller, for during the trials there was very little vibration in the stern of the boat throughout the range of speed of the engines. Cutless rubber bearings furnished by the Goodrich Rubber Company are used in bearings in the intermediate strut and in the shaft bearings abaft the propeller. The bearings in the stern tubes are made of babbitt and are lubricated by oil supplied by a 50-gallon lubricating oil tank located in the engineroom.

GENERAL DESCRIPTION OF MACHINERY.

The main engines were built by the Winton Engine Corporation. These engines are six-cylinder, four-cycle, airless-injection, Diesel engines, with a 14-inch bore and 16-inch stroke, and are designed to develop 670 horsepower each at 450 R.P.M. The engines are direct connected to the propellers.

These engines are direct reversible, reversing being accomplished by sliding the camshaft, thereby bringing the reverse cams under the rocker arms. The camshaft is built up, having a high carbon steel shaft with two sets of hardened molybdenum steel cams, one set for ahead and one for astern operation, held to the shaft by steel taper pins.

All castings for these engines, such as cylinder blocks, top and bottom crankcases, cylinder liners and cylinder heads, were cast

from chrome nickel iron. The cylinder head for each cylinder was cast separately and completely water jacketed. They are designed so that they may be removed without dismantling the intake or exhaust manifolds.

The pistons are made of Bu-Nite, an alloy of nickel, copper and aluminum. They are of the trunk type, ground the full length and fitted with six piston rings. The pistons carry the wrist pin bearings which are lubricated from the main oiling system.

The crankshafts are nine inches in diameter, forged of open hearth steel, machined all over and double drilled for lubrication.

The connecting rods are steel drop forgings, fitted with detachable journal boxes. These boxes are made of bronze lined with high grade babbitt scraped to fit the crankpins.

The valves are special alloy steel forgings with head and stem integral. All valves are mounted in removable cages. The exhaust valve cages are water cooled.

The valves are actuated by rocker arms which operate from an overhead camshaft. These rocker arms are steel drop forgings, bronze bushed and carry hardened steel rollers and pins at each end.

The injection valve is of needle type opening outwardly. Regulation of fuel consumed by the cylinders is obtained by increasing or decreasing the oil pressure and by varying the duration of opening of the fuel valve.

A Kingsbury thrust bearing is used abaft each engine which is designed to absorb the forward or astern thrust of the propellers.

Attached to the engines are circulating water pumps for supplying cooling water to the cylinders, lubricating oil pumps for the lubricating oil system, high pressure fuel oil pumps which supply fuel oil at high pressure to the injection valves, and fuel oil transfer pumps which transfer oil from the bunker tanks to the fuel oil service tank.

Each engine has its own cooling system consisting of a sea valve, oil cooler, pumps mentioned above, water jacketed cylinders and cylinder heads, and overboard discharge connections. The sea valves are cross connected so that either one may be used to supply circulating water to the engines if one of the sea valve strainers should be clogged with ice. As an additional precaution, the fire

pump is cross connected with the circulating water system so that it will take its suction from the main sea valves through the oil coolers and discharge into the headers which distribute the circulating water to the cylinders of each engine. This feature in the piping arrangement makes it possible to operate the engines even though their circulating pumps may not be in working order.

The lubricating oil system used in the main engines is pressure feed system supplying oil under pressure to all parts requiring lubrication. The oil is forced under pressure by an attached pump into the lubricating oil header in the crankcase. From this header, oil is delivered to the main crankshaft bearings, then through passages drilled in the crankshaft to the connecting rod bearings, and up each connecting rod through a tube to the wrist pin bearings. Oil drains back to the crank case sump where it is taken by another attached pump and delivered to the cooling and filter system. This system will be described in a later paragraph.

The main engines are equipped with governors of the flyball type. The governors are geared to the camshaft and are set so as to shut off the fuel oil supply to the engines at 10 revolutions above their rated speed.

The electric generating equipment consists of two 15-Kw. generating sets and one 5-Kw. generating set. The 15-Kw. sets are direct connected to Winton Diesel engines. The 5-Kw. set is direct connected to a Winton Diesel engine and has an extended shaft at the commutator end of the generator to which a Worthington two-stage air compressor is connected through a clutch. The generators were all furnished by the Westinghouse Electric Company and are designed to deliver their rated output at 600 R.P.M. The engines driving the 15-Kw. generators have three cylinders with a bore of 5 inches and a stroke of 7 inches. The engine driving the 5-Kw. generator has two cylinders with a bore of 5 inches and a stroke of 7 inches. All the engines have mechanical injection of fuel oil and are electrically started. Starting batteries for each engine are provided and installed on foundations located on the bulkhead adjacent to the engines. The engines are equipped with fuel pumps, water pumps and lubricating oil pumps, all driven from the engine to which they are attached. The two 15-Kw. generators each generate current at 125 volts, while the 5-Kw. genera-

tor generates current at 140 volts for battery charging and 120 volts for lighting and power for port use.

The main air compressor unit consists of a two-cylinder, two-stage, Ingersoll-Rand air compressor, driven by a motor furnished by the Westinghouse Electric Company. The compressor cylinders have a bore of 5 inches and 2½ inches, a stroke of 4 inches, and a displacement of 40 cubic feet of air per minute at 875 R.P.M. The motor is drip proof, compound wound, and develops 12½ horsepower when operated on 120-volt direct current.

Ten starting air tanks have been installed in the engineroom in order to provide ample air for maneuvering. These tanks were furnished by the Winton Engine Corporation. They have a capacity of about 9.3 cubic feet each and are made of welded steel plate to stand a working pressure of 400 pounds per square inch.

The whistle air compressor was furnished by the National Brake and Electric Company. The compressor has two cylinders and is driven by a 120-volt direct current motor. The system is arranged so that the pressure in the whistle air storage tank is automatically maintained within the range of pressures required for the air whistle.

The air whistle was made by the Allan Cunningham Company. Sound is produced by a vibrating disc which is made to vibrate by the air blowing through the whistle.

In addition to the fuel oil pumps attached to the engines, two additional transfer pumps have been provided, one a hand pump and the other a motor driven pump. The hand pump was made by Goulds Pumps, Inc., and is a rotary cam type of pump. This pump takes it suction from the main fuel oil tanks and from the fuel oil drain tank and discharges to the fuel oil service tank and to the fuel oil tank for galley range and heating boiler. The power driven fuel oil transfer pump is a rotary type pump driven by a motor furnished by the Westinghouse Electric and Manufacturing Company. The motor is a drip proof, compound wound, direct current, 120-volt motor, operating at 700 R.P.M. The pump takes its suction from the main fuel oil tanks and discharges to the fuel oil service tank and to the fuel oil tank for galley range and heating boiler. All suction and discharge lines are fitted with duplex strainers.

The lubricating oil system consists of two attached pumps, two independent pumps, two coolers, two filter tanks, an oil purifier, and storage tanks for fresh oil and used oil. The attached pumps are the reciprocating plunger type furnished with the engines by the Winton Engine Corporation. The two independent pumps are both rotary pumps furnished by the Viking Pump Company, and are so connected through gears that they are both driven from the same motor. The lubricating oil coolers were made by Schutte and Koerting Company. The coolers are shell and tube type with water passing through the tubes in a single pass and the oil around the tubes with baffles arranged so that the oil will not pass directly from the inlet to the outlet connections but around the baffles. The filter tanks were furnished by the Winton Engine Corporation and consisted of two filter compartments, each arranged so that one compartment could be used while the filters in the other one were being cleaned or renewed. The filters consist of brass gauze strainers arranged so that all oil passing through the filter tanks must pass through these strainers. The lubricating oil purifier was furnished by the Hydroil Corporation and consists essentially of a motor driven centrifugal purifying bowl, an electric oil heater and two attached pumps, one for suction and one for discharge. The lubricating oil storage facilities consist of 280 gallons of new oil and 135 gallons of used or purified oil. A 50-gallon tank has also been provided to supply lubricating oil to the babbitted bearings in the stern tube.

The lubricating oil piping to the main engines is arranged so that one of the attached pumps will take oil from the crankcase sump and deliver it to the filter tank. The other pump is connected so it will take oil from the filter tank through the oil cooler and discharge it to the oil distribution piping system in the engine in which it is delivered to bearings and all parts which require pressure lubrication. The independent lubricating oil pumps are arranged as standby pumps for the pumps attached to the engines, as one pump takes oil from the crankcase and discharges to the filter tank while the other one takes it from the filter tank through the cooler and discharges to the lubricating oil piping in the engine. These independent pumps are arranged so that they can be used on either

or both engines. The purifier has a suction pump which can take its suction from the crankcases of either of the main engines, or any of the auxiliary engines, and discharges to the purifier bowl through an oil heater arranged to control the temperature of the oil being purified. The purifier bowl drains into a funnel attached to the suction side of the discharge pump attached to the purifier. The discharge of this pump leads to the used-oil storage tank which in turn can drain back into the lubricating oil system of the main engines.

The sanitary system is hydropneumatic, the storage tank being maintained under pressure by a motor driven pump. This pump was furnished by the Warren Steam Pump Company and is a single stage, double suction, centrifugal pump driven by a 5-H.P. Diehl motor turning at 1750 R.P.M. This pump takes its suction from a sea valve and discharges to the sanitary system pressure tank. The sanitary system supplies water to showers and to the flushing valves of crew's and officers' toilets. This system has a connection on deck so that it may be connected to a fresh water line ashore when in port, thus giving a supply of fresh water for showers.

The fresh water system is operated solely by rotary hand pumps. Pumps are installed in the crew's washroom and at the officers' lavatories for washing purposes only. A hand pump in the galley supplies drinking water from the drinking water tank for cooking and other purposes in the galley.

The fire pump is a two-stage, hydraulically balanced, centrifugal pump furnished by the Warren Steam Pump Company. The pump is driven by a 10-H.P. Diehl motor at 1750 R.P.M. The fire pump takes suction from a sea valve from the water connections of the lubricating oil coolers and from the engine room bilge. It discharges to the fire system, overboard and to cross connections to the sanitary tank and to the main engine cooling water system.

The bilge system consists of five water jet bilge eductors operated from the fire system, a bilge suction from the fire pump in the engine room bilge, and a hand pump on deck for pumping water from the engine room bilge. This hand pump discharges overboard and also to the fire system.

In order to ventilate the engine room bilges, a blower has been installed which draws air from the bilges in the engine room and discharges it above the weather deck. The blower for this purpose is a Sirocco Utility Blower—American type, with a capacity of 320 cubic feet of air per minute when run at 1725 R.P.M.

The propellers have a diameter of 62 inches and a pitch of 53 inches. The projected area ratio is .400. Each propeller turns outboard. The propeller shafting outside the hull is fitted with fairwaters adjacent to the shaft struts and propeller hub in order to reduce eddy resistance as much as possible. The shaft struts are single arm struts with the arms streamlined to reduce their resistance to a minimum.

TRIAL RESULTS.

The builder's trials of the *Thetis*, the first of the new 165-foot patrol boats to be completed, were run on the Rockland, Maine, trial course on November 19, 1931. The trials were run by making two runs over the trial course in one direction and one run in the opposite direction at each speed. The trials were run at four different speeds in order to obtain data for a standardization curve for these boats. On December 1, 1931, after the *Thetis* had been commissioned by the Coast Guard, additional speed trials were run in order to determine the speed of the *Thetis* at engine speeds in excess of those obtained during the builder's trials. The results of both of these trials are tabulated below:

	Run 1	*Run 2*	*Run 3*	*Run 4*	*Run 5*
Speed in knots	7.306	11.074	13.245	16.067	16.555
R.P.M.	186.0	291.8	359.7	457.6	476.8

The first four runs were made during the builder's trials, while the last run was made by the Coast Guard after the *Thetis* was commissioned.

The builder's trials were made at full load displacement, all weights not on board at the time of the trials were compensated for by having a ballast of equal weight stowed on board during the trials. During the trials run by the Coast Guard, the *Thetis* was loaded so that its displacement was the same then as it was during the builder's trials.

The trial board's report of the builder's trials showed that the machinery functioned satisfactorily throughout the standardization trials and the two hour full speed trials which were run while the *Thetis* was returning to Bath from the Rockland trial course. The trial board found that the *Thetis* had a period of roll of 5½ seconds. The tactical diameter of the turning circle when making a speed of 16 knots was found to be about 200 yards. The *Thetis* was brought to a dead stop from full speed ahead in 50 seconds and within 200 yards of its position when the first signal was given. The elapsed time to change the engines from full speed ahead to full speed astern was 30 seconds.

MATSON LINER S.S. *MARIPOSA.*

Description and Trials.

By Captain O. L. Cox, U. S. N., Member.

The *Mariposa* is the first of three sister vessels now being built by the Bethlehem Shipbuilding Corporation, Ltd., at their Fore River Plant, Quincy, Mass., for the San Francisco-Australian service of the Matson Line.

These vessels are built in conformity with the Jones-White Act and in accordance with the latest rules of the American Bureau of Shipping, and the plans approved by the U. S. Shipping Board and Navy Department. She conforms to American Bureau of Shipping Classification ✠A-1 (E). Preliminary plans and specifications were prepared by the Matson Company and their consultants, Mr. Hugo P. Frear, Naval Architect, and Mr. John F. Metten, Marine Engineer. Detail plans and specifications were prepared in conjunction with the technical staff of the Fore River Plant and the contract signed on October 25, 1929.

PRINCIPAL DIMENSIONS AND CHARACTERISTICS.

Length over all, feet and inches	631 6 5/8
Length on D. W. L., feet and inches	628 0
Length B. P. (to C. L. of rudder stock), feet and inches	605 0
Breadth molded, feet and inches	79 0
Breadth extreme, over "B" deck, feet and inches	82 1½
Depth molded to "B" deck, feet and inches	61 0
Depth molded to "C" deck, feet and inches	52 9
Depth molded to "D" deck, feet and inches	44 6
Draft, molded, to D. W. L., feet and inches	28 0
Displacement, to D. W. L., tons	26,141
Gross tonnage, U. S., tons	18,017.35
Net tonnage, U. S., tons	10,580
Cargo capacity—general, cubic feet	245,019
Cargo capacity—refrigerated, cubic feet	34,629
Cargo capacity—baggage, mail, etc., cubic feet	29,974
Fuel oil capacity—total, tons	6,606

Fresh water capacity, tons		2,439
Drinking water capacity, tons		430
Passenger accommodations, first class	475	
Passenger accommodations, cabin class	229	
		704
Crew—Deck department	46	
Engine department	46	
Stewards' department	240	
Purser's department	12	
Medical department	3	
Watchmen	12	
		359
Total persons on board		1063
Shaft horsepower, normal		22,000
Service speed, knots		20½
Contract signed		25 October, 1929
Keel laid		11 June, 1930
Launched		18 July, 1931
Delivered		14 December, 1931

DESCRIPTION OF HULL.

The hull is of the complete superstructure type, having nine decks, four of which are almost exclusively for passengers. The framing is transverse and frames are spaced 36 inches apart amidships and gradually reduced towards the ends to 24 inches. The hull is divided into thirteen main compartments by twelve watertight bulkheads. Fuel oil tank and other minor bulkheads add further to the subdivision. The ship is designed to remain afloat and with sufficient stability to prevent flooding undamaged compartments when at least two major compartments are open to the sea. The double bottom is continuous from fore peak to aft peak bulkheads and is fitted to carry fuel oil and water.

GENERAL ARRANGEMENT.

This arrangement provides two large cargo holds forward, just aft of the collision bulkhead and fore peak tank; each hold is served by a hatch of generous proportions. Cargo space is provided well down in the ship, the upper part of these main compartments, on "E" deck and above being used for accommodations for crew. A large block of fuel oil tanks, above and separate from the inner bottom, comes next to the cargo space; then the forward boiler room. Another block of fuel oil tanks separates the forward

and after boiler rooms, then comes an auxiliary machinery space in which are located pumps and generators and the like, and which is flanked by oil tanks at the side of the ship. The main engine room comes next, followed by refrigerating machinery space and fresh and drinking water tanks. These tanks run aft beside the propeller shafts; then at the after end of the hold is a trimming tank. Refrigerated cargo space is provided aft; also space for a considerable amount of general cargo. Refrigerated ship's stores are near the refrigerated cargo and machinery space. Other ship's stores, laundry room, baggage spaces, mail room and tailor shop fill in where convenient on lower decks between the forward and after holds.

The main dining saloon, galley, pantries, and cabin class dining saloon are located amidships on " E" deck—the first deck wholly above the deepest load water line. " D," " C," and " B" decks are given over mainly to staterooms. " A" deck has 10 de luxe staterooms forward, eight of which have " lanais" or private enclosed verandas. These rooms may be made up into suites as desired. The rest of " A" deck is given over to public spaces, and provides an extensive promenade, a library, a writing room, a large lounge, an extensive smoking room, a men's club-room and bar, and a dance pavilion and palm garden which extends the full width of the ship and has large windows on three sides. On the boat deck, next higher than " A" deck, are the navigating spaces, officers' quarters, and radio room, in a house forward; accommodations for engineer officers and the officers' mess room amidships; and for the passengers, a well equipped gymnasium and an electric bath, as well as a large amount of promenade deck space. A tennis court is found on top of the house over the main lounge, and a large sport deck above the dance pavilion.

The cabin-class is given exceptionally fine accommodations, the staterooms here being as well appointed as those of the first-class. For the use of the cabin-class is provided a very comfortable and attractive lounge, a large and excellent smoking room, a veranda enclosed on three sides, and a generous amount of deck space, all in addition to the cabin dining saloon mentioned above.

Each class of passengers has at its disposal a large open air swimming pool.

Many awnings are provided for shelter in hot weather.

The two smokepipes are spaced far apart, about equidistant from amidships, giving a well balanced appearance.

The vessel has a slightly curved stem, raking forward, and the cruiser type of stern.

The rudder is of the balanced, streamline type, having a cast steel frame with some structural stiffening and support for the side plates. It is carefully faired, and its greatest thickness is no less than two feet. The rudder stock is one piece of cast steel, two feet diameter outside with a ten-inch core, shaped at the lower end to form a large horizontal coupling to the rudder frame. Keys and fitted bolts hold rudder and stock rigidly together; particular care was used in the design of rudder and stock in order to develop ample strength in these parts to withstand severest conditions of service.

The fuel oil tanks are located amidships, and have greater capacity than is actually required for an entire round trip between California and Australia. Fresh water and drinking water tanks provide ample capacity to meet all requirements of passengers and crew. A pipe passage runs fore and aft through the oil tanks between the boiler rooms for the purpose of carrying steam and other piping as well as for access; and a similar tunnel runs through the forward oil tanks to carry piping for oil and to the forward double bottom and fore peak tanks.

Access through watertight bulkheads between compartments is obtained by steel watertight doors, thirty-two in all, located on and below "C" deck. Twenty of these doors are of the horizontal sliding type, and are operated electrically from the bridge, or manually at the location of each door if desired. The other twelve doors are of the hinged type, operated by hand. None of these doors are located below the normal load waterline, all doors below "F" deck, and several above, being of the horizontal sliding type.

These electrically operated doors, when operated from the bridge, can be operated singly or all at once; an alarm is connected with each which rings a gong and closes a safety gate before the door itself operates.

Masts are of steel, built up and riveted.

Cargo booms are of steel tubing.

A feature of the *Mariposa* is that the side plating of the hull is insulated with cork slabs in way of passenger accommodations, the entire length of passenger space on "C" and "D" decks being so insulated; also in way of the dining saloons and cabin passenger space on "E" deck. On the boat deck, the sides of the deckhouses enclosing deck officers' and engineer officers' quarters, gymnasium, and electric bath are similarly treated. These cork slabs are one inch thick and are permanently fastened to the plating. They are, in general, covered by ornamental sheathing in quarters. Similar insulation, but of one-and-a-half inch slabs, is used in way of the hospital spaces on "E" deck forward.

This insulation, together with the white paint on the entire outside of the ship above water, should provide comfort in the hottest weather as well as freedom from moisture due to condensation.

CARGO HANDLING.

The *Mariposa* is equipped to carry general cargo, automobiles, and refrigerated cargo. The cargo space is divided forward into two large holds, not insulated, for general cargo. Aft, there are refrigerated spaces and additional space for general cargo. Side ports are provided both forward and aft, those forward opening onto "F" deck, those aft, into both refrigerated and general cargo space on "F" deck. Additional side ports are provided on "E" and "F" decks amidships, for baggage, mail, and stores; and for entrances for passengers and crew. Still others are located on "C" and "D" decks for passenger entrances. All cargo forward is carried on or below "F" deck, the space above being used for crew's accommodations. Hatches on deck serve each of the two forward holds, being carried as trunks through the crew spaces on "C," "D," and "E" decks. The upper part of No. 2 hatch, which extends to "B" deck, is utilized as a swimming pool for first-class passengers, watertight steel hatch covers being fitted about on the level of "C" deck and proper filling and draining connections being made above. Aft, the cargo is carried on "F" and "G" decks, and is handled through a hatch from "B" deck. Similarly to No. 2 hatch, this hatch aft is used for a swimming pool, in this case for cabin-class passengers.

Cargo booms are fitted as follows: On the foremast, four booms of five-ton capacity each and one of thirty-ton capacity; on the mainmast, two of five-ton capacity each. In addition, two five-ton booms are fitted on the forward end of the deck house, over No. 2 hold. Aft, two kingposts are fitted, one at each side of the ship, each having a five-ton boom serving the after cargo hatch.

All cargo winches are electrically driven, with controls placed where each operator can run two winches and still see down into the hatch where those winches work. Winches were made by the Allan Cunningham Company in Seattle, and are driven by Westinghouse motors. Two of the winches are of the double reduction geared heavy duty type for use on heavy loads on the thirty-ton boom; the others are of single geared high speed type. All winch motors are rated at 35 horsepower at 300 R.P.M., and are watertight.

All cargo gear is made in accordance with the stringent regulations for cargo handling of the Australian government, which require each part to be marked with the load to which it has been tested and gear to be so arranged that frequent inspection of all gear is possible, and that certain steel parts can be removed periodically for annealing.

OPERATION.

A complete Sperry gyro-compass system is provided, with master gyro-compass and controls in an electric station on the boat deck, and repeater compasses in the wheel house, captain's room, radio compass room, bridge wings, port and starboard, on the flying bridge, and in the steering gear room. A gyro-pilot, or "Metal Mike," is installed in the wheel house, and is of the double-unit type electrically connected to the power unit in the steering gear room.

Ten-inch standard compasses, furnished by the Kelvin and Wilfrid O. White Company, are fitted in customary locations, one in the wheel house and one on the flying bridge.

A Sperry course recorder is installed in the chart room.

A Sperry self-synchronizing rudder angle indicator system is installed, with repeaters in the wheel house, engine room, and steering gear room. There is also a Sperry shaft revolution indi-

cator system, with indicators in the wheel house and engine room and an electric comparator for indicating the comparative speeds of the shafts at a glance.

The latest Submarine Signal Company type of Fathometer is installed, which gives a continuous record, if desired, of the depth of water in which the ship is running. The recording mechanism is located in the wheel house.

Two Lietz sounding machines, motor driven, are fitted, one on either side of the navigating bridge.

Engine, docking, and steering telegraphs are of the latest alternating current Navy type, and were made by Charles J. Henschel and Company, Inc. They consist of combined engine order transmitters and indicators for each shaft at each side of the wheel house, with repeat-back indicators at each throttle valve; docking telegraph with similar repeat-back indicators taking orders from the bridge to the docking station on "D" deck aft; and a steering order telegraph with transmitter in the wheel house and indicator in the steering gear room.

A fire room telegraph of the same make and type is installed to take orders from the central gage board in the engine room to indicators in each fire room. Repeat-back indicators are fitted to these also.

Separate duplicate motor generators with power supply from the emergency bus are provided to operate these telegraphs.

Two Sperry eighteen-inch incandescent searchlights are fitted, one on top of each bridge-wing shelter.

A pitometer log was supplied to the ship by the Kearfott Engineering Company, and a Walker-Trident electric log, by Kelvin and Wilfrid O. White Company.

Two Kent clear-view screens, consisting of a rapidly rotating disc of glass, were furnished by the Charles Cory Corporation, and are installed in the wheel house.

McNab automatic electric whistle controls with secondary mechanical control are provided for both whistle and siren.

For hand steering from the wheel house, McLeod hydraulic telemotor control is fitted. An emergency control is fitted in the steering gear room.

The radio equipment is of the latest type, and includes radio direction finder, radio transmission and receiving sets, and ship-

to-shore radio telephone equipment. A radio-operated clock is installed in the radio operating room. The transmitting set is of 500-watt size. The radio equipment was furnished by the Radiomarine Corporation of America.

In connection with oil and water tanks, pneumercators are fitted to all oil and drinking water tanks, and to other water tanks under the refrigerated cargo space where sounding is difficult. These instruments were furnished by the Pneumercator Company, and record at all times the amount of fuel or water in each tank.

The ventilating and heating system follows the latest marine practice of supplying to each stateroom and to all public rooms fresh warm or cool air, the temperature at all times being controlled by passenger or steward. This fresh air is supplied under pressure at rates sufficient to change the air in each space in times varying from three to six minutes, according to the use of the space. In this way, passengers in all staterooms, inside and outside, are assured of a constant supply of fresh air at an appropriate temperature; and may themselves regulate the amount of air supplied by means of the Punkah louvres fitted in every room, which enable the passenger to direct the flow of air in any direction or to shut it off altogether. Air escapes from the staterooms through ventilators in the baths or toilets. Exhaust fans are also connected to certain spaces, such as the galleys, public lavatories, and storerooms and workshops where required. Each stateroom on "A" and "B" decks is provided with an outlet for a portable electric heater, which may be used in times of unusual cold. Radiators are not installed in passengers' staterooms, the ventilating system making them unnecessary.

Officers' and crew's quarters are heated by steam radiators; ventilation on the boat deck is natural, and below the boat deck in these quarters it is forced.

The fresh air supplied to the dining saloon is put through a special conditioning system which washes and dries the air and brings it to the desired temperature—warm or cool, according to the weather. This air conditioning system is here used for the first time on an American built ship, and the second time on any ship.

Extensive protection against fire is provided. Fire screen doors are fitted in strategic locations throughout the ship for the pur-

pose of confining a fire, should one occur, to as small a space as possible, and to prevent it from spreading from one deck to another. They are properly divided into two groups—fire screen or fireproof doors, fitted in corridors and at entrances to public rooms, and roller fire doors, fitted at stairways. Of the first group, fire screen doors, no less than thirty are fitted throughout all parts of the passenger space. These doors are in many cases designed to harmonize with the surrounding decorations, and are, therefore, difficult to recognize as being different from other doors. Several of them are even fitted with glass panels, a special type of glass passed by the fire insurance underwriters being used in these cases. Of the roller fire door type, fourteen are installed, in general at the landings on each deck at each main stairway. Normally, these doors are rolled up into casings in the tops of the door frames, and thus disappear entirely from view.

A fire main, carrying water under pressure, is fitted throughout the ship, with hydrants installed in a manner which permits all parts of the ship to be reached with a short length of hose. In all, ninety-two hydrants are fitted. Connections are made to the fire main for filling the swimming tanks.

Hand fire extinguishers of the chemical type are provided throughout all parts of the ship. Pyrene carbon-tetrachloride extinguishers are located in the space where it is intended to carry uncrated automobiles.

Lux carbon dioxide fire extinguishing system is installed to cover boiler rooms, cargo holds, oil filling stations, paint lockers, lamp room, and storerooms.

Steam smothering lines are fitted to all fuel oil tanks and to the paint locker in the auxiliary machinery room.

Lifeboats are carried on gravity davits of the Welin-McLachlan type. All boats and davits were supplied by the Welin Davit and Boat Corporation. The following boats are carried:

No. of Boats.	*Size and Type.*	*Capacity Each Boat.*
2	26-foot motor boats, metallic	10 persons
14	30-foot lifeboats, metallic	70 persons
4	26-foot lifeboats, metallic	40 persons
2	20-foot lifeboats, wooden	18 persons

The four 26-foot boats are nested inside four 30-foot boats. Two sets of regular Welin quadrant davits, hand operated, are furnished for the 20-foot boats which are intended for use as workboats and are the only ones not carried on gravity type davits with electric hoisting gear. The motor lifeboats are provided with cabins and are fully equipped for service, each carrying a radio outfit as part of its regular equipment.

Anchors are supplied as follows:

2 Bower anchors	17,150 pounds each
1 Spare bower anchor	14,595 pounds
1 Stream anchor	6,195 pounds

These anchors were made by the Baldt Anchor Chain and Forge Corporation.

The windlass is of the horizontal spur geared type, made by the Bethlehem Shipbuilding Corporation, Limited. Dual electric motor drive is provided, Westinghouse motors of 50 horsepower each at 600 R.P.M. being used. The windlass and motors are mounted on the forecastle on one bedplate, the motors being watertight.

On the forecastle also are two capstan heads, with the machinery on the deck below. Two more capstans are installed on "D" deck aft, capstans and motors in one unit on a common bedplate here. All these capstans are of American Engineering Company make, and are driven by Westinghouse watertight motors of 75 horsepower each at 600 R.P.M.

The steering gear is of the hydraulic ram type, having four single-end cylinders arranged fore and aft at a slight angle to conform to the shape of the hull. Two cylinders are aft and two forward of the tiller, to which they are connected by sliding blocks. The gear is actuated by electrically driven pumps, with two Westinghouse motors each rated at 75 horsepower at 400 R.P.M. The steering gear was made by the American Engineering Company. Emergency hand control is provided.

HOTEL SERVICE.

The galley is located on "E" deck, between the main and cabin dining saloons, and serves both. It is thoroughly modern and well equipped.

Eight Westinghouse electric range sections are placed together to form one big range in the central part of the galley. In addition there are two Edison electric automatic fry kettles, two Mitchell Woodbury charcoal broilers, steam tables, boilers, warmers, coffee urns, etc., etc.

Food for the officers' mess is prepared in the main galley and sent up by the dumbwaiter to the pantry on the boat deck. There are deck pantries fitted on the "A," "B," "C" and "D" decks to serve beverages, ices, etc., in staterooms and public spaces.

The crew's galley is located forward and is completely equipped for serving food to the crew.

The laundry is located on the "F" deck amidships and is a completely equipped modern laundry capable of taking care of all laundry work required by ship and passengers.

A tailor shop is provided for necessary valet service.

Refrigerators in the galley, deck pantries, and first-class soda fountain and bar are connected to the ship's refrigerating system. Those in the crew's galley and in the cabin bar are individual units, and were supplied by the Brunswick-Kroeschell Company.

The plumbing systems include hot and cold fresh water systems over the whole ship, a cold salt water sanitary system, and a circulating ice water system.

Cold fresh water is stored in designated tanks in the double bottom and hold, and is pumped from these tanks into the main system, which is kept constantly under pressure. Fresh water heaters are provided in the engine room, and the hot water circulates at all times through piping which takes it near all hot water faucets, enabling hot water to be obtained anywhere in a moment. The heaters are designed to keep the water at a temperature of 140 degrees Fahrenheit.

The sanitary system is supplied with cold salt water. No salt water is supplied to passengers or crew for personal bathing purposes, fresh water only being supplied for that use. No connection is made between salt and fresh water systems.

The ice water circulating system maintains a supply of cold water to drinking fountains and drinking water supply taps in all parts of the ship. The ice water is pumped through two loops, one forward and one aft, from a chilled storage tank. Short leads

are taken off from these loops to the different outlets in galleys, pantries and mess rooms; and really cold water is thus obtained very quickly at any outlet.

Fresh cold water, not iced, is also supplied from the drinking water tanks to galleys, pantries, and mess rooms, for cooking purposes and drinking.

All water for cooking and drinking is stored in tanks separate from other fresh water tanks. Washing water in staterooms and elsewhere is clearly labelled " Not for Drinking."

The *Mariposa* is one of the earliest ships on which every first class room has a private toilet. In addition, the majority of first class rooms have a private bath or shower, or a bath for the use of either of two adjoining rooms. First class rooms on " D" deck are so arranged that a bath is convenient to each group of four rooms, being located at the end of, and entered from, the short passageway that serves those rooms, and being, therefore, of a semi-private nature.

Every stateroom is supplied with hot and cold running fresh water.

Cabin class rooms are well supplied with toilet facilities; though private baths are not fitted here, public lavatories and baths are ample in number and size, and are extremely well appointed.

Plumbing fixtures throughout the ship were supplied by the Noland Company of Newport News, and were made by the Standard Sanitary Manufacturing Company; the single exception being that Sloan flush valves are used throughout.

PASSENGER ACCOMMODATIONS.

Staterooms are large and are very complete in appointments; and every detail making for the comfort of the passenger has been carefully looked after.

The fittings and decorations of rooms of the first and cabin class accommodations are practically identical. This seeming coincidence enables the ship to be used as a one class ship if desired simply by leaving open the doors which are ordinarily closed to form the divisions between classes.

Beds are provided in all rooms, throughout first and cabin classes, made of steel in imitation of bamboo. Each stateroom has

a bureau, large wardrobes, light but strong wicker chairs, running hot and cold water, ice water in large thermos pitchers, and a telephone. On the side of each bureau is a convenience outlet on the 115-volt system which may be used for electrical appliances, such as curling irons and fans, as desired by the passenger.

The first-class rooms have beds only—no upper berths—and are arranged for one and two persons. Fifty-seven rooms are single, and 209 double. Double rooms are mostly equipped with twin beds, though there are double beds in several. Many of these rooms are arranged to be used as suites, doors between adjacent rooms being provided. Some combinations are worked out whereby rooms may be combined in suites of either two, three, or four rooms, in some cases with parlors in addition, or may be used as single rooms, as may be desired on occasion. Trunk rooms are provided with some of these suites. Each first class stateroom is furnished a folding card table, stowed in a rack beneath the bed.

Cabin-class rooms have been arranged for two, three, and four persons, 3 for two persons, 33 for three persons, and 31 for four persons. Beds are provided in all of these rooms, and one or two upper berths as required. These upper berths were especially designed for the *Mariposa* and her sister ships. They are of the folding type, with a double hinged arrangement which permits each to fold up into a shallow built-in box high up in the room, leaving almost full headroom over the beds. The rooms thus appear to have no upper berths at all, which greatly augments their apparent size compared to the usual three- and four-berth rooms. All cabin-class rooms are very fully equipped, and their standard furnishings are of the same type and quality as those of the first-class rooms.

Two passenger elevators are provided, one running from the boat deck to "E" deck inclusive, the other from "A" deck to "F" deck inclusive. An engineers' elevator is also installed, running from the boat deck to "F" deck inclusive, in way of the engineers' quarters; a crew's or ship's stores elevator, from "A" to "F" decks; and two baggage elevators, between "E" and "F" decks only. The dumbwaiter between officers' mess and galley is also electrically operated. All were supplied by the Otis Elevator Company.

Barber shops and beauty parlors are supplied for both first class and cabin passengers.

A broadcasting system is installed on board which distributes entertainments or lectures given on shipboard as well as radio programs from shore which are picked up by the ship's own receiving set. Provision is made for microphones to be installed in the main lounge and dance pavilion and at the Captain's table in the main dining saloon; loud speakers are installed in all public spaces, on deck, and in private verandas and parlors of suites for use when desired by the passenger.

Two duplex talking picture systems have been provided for the entertainment of the passengers. One is installed in the main lounge; the other in the cabin lounge.

These radio and talking picture installations were made by the R.C.A.-Victor Company and the R.C.A.-Photophone Company.

Deck covering throughout all passenger space, in public rooms, staterooms, and corridors, and on stairways, is rubber tile, all supplied by the United States Rubber Company. Carpets and rugs used in staterooms, foyers, public rooms, and elsewhere as found appropriate.

A fully equipped gymnasium for the benefit of passengers is provided on the boat deck. All gymnasium outfit was furnished by A. G. Spalding and Brothers.

Adjacent to the gymnasium is an electric bath, which might be described as a modernized turkish bath especially suited to use in the tropics. Electric bath cabinets here were supplied by the Hospital Supply Company. Showers, needle sprays, foot baths, and other similar equipment are here located.

The number of staterooms on board the *Mariposa* is as follows:

266 first-class rooms, accommodating 475 passengers.

67 cabin-class rooms, accommodating 229 passengers.

The seating capacity of the main dining saloon is 376 persons; and of the cabin dining saloon, 134 persons.

INTERIOR DECORATION AND FURNISHINGS.

The interior decoration of the *Mariposa* is the work of Warren and Wetmore, Architects, of New York City. Joiner work was done by Hopeman Brothers, of Rochester, New York, who worked

in conjunction with Warren and Wetmore to produce furnishings of a style appropriate to the service in which the *Mariposa* is to be used. With service in the tropics in mind, the decorators selected soft cool colors for the interiors of the *Mariposa;* and the Oriental and Chinese Chippendale effects used are reminiscent of the South Seas and islands therein to which the ship is designed to sail.

The keynote of design is simplicity and beauty without ornate and elaborate decorations. Furniture throughout the ship is light in appearance and cool in effect. Rattan and cane are much used, finished both naturally and in vivid contrasting colors. Heavy appearing hard wood is entirely eliminated from the decorations in the first class quarters, appearing only in the curly mahogany bar counter in the Men's Club Room. Drapes and curtains are entirely omitted in the first class; carved wood grilles in soft tones are substituted for them at windows in public rooms.

The general color scheme used is soft, pale tints of gray, green and blue.

Corridors, foyers, and stairways are free from heavy moldings and pilasters. Corridor walls and ceilings are generally finished in pale French gray, and floors are covered with blue and light gray rubber tile. Stateroom doors in corridors are given a coat of dull silver, and door frames are painted pale blue. Foyers are similarly finished in grayish green with gray and green rubber tile floors.

The staterooms are finished, in most cases, with cool grayish green, with touches of bright coloring in the rattan chairs and the shades for the bed and dresser lights. Beds are of metal, of the appearance of bamboo, and were designed especially for the ship.

Furniture in the four special suites de luxe is, to some extent, of the Chinese Chippendale style.

The first-class lounge is about fifty feet square and fifteen feet high. The decoration is a rather broad adaptation of Chinese Chippendale, with mural decorations from floor to ceiling consisting of quaint Oriental figures and foliage in the style of Pillement, painted in soft coral tones on a background grading smoothly from golden yellow at the bottom to deep turquoise blue at the top. The windows are screened with carved wood grilles, which are finished in antiqued gold leaf. All windows and doors have cano-

pies of carved wood in gold and turquoise color, with valences of Philippine "Kapa" shell—a translucent, faintly colored sea shell. The lighting is derived from four large indirect fixtures arranged on four slender, clustered columns in the room. These fixtures are in the form of inverted flaring bells of "Kapa" shell and gilded bronze, the shell being graded from soft yellow at the bottom to turqoise blue at the top, giving a very pleasant combination of direct and indirect lighting. The ceiling is smooth flat white, without beams, and is especially appropriate for indirect lighting. Above each window and forming part of the window treatment is a rosette of "Kapa" shell, with reflector lights behind, which adds a soft, opalescent light to that from the four main fixtures. The furniture here is principally rattan, with gray colored binding and deep, comfortable cushions in shades of blue, green and gold. The floor is covered with rubber tile in a basket pattern of soft blue and green.

The writing room is decorated with charts and mural paintings depicting the Pacific Ocean and the ports of call from San Francisco to Australia. The charts are in old parchment color and the murals in soft pastel shades. The panel mouldings framing the murals, the low wood dade, and the cornice and ceiling are all painted soft old ivory color. Desks are painted a soft dull yellow; the chairs revolve on fixed bases, and are painted to match the desks, having upholstered seats of green, coral, and silver brocade. Each desk has a desk lamp of rock crystal in Chinese pattern; and flat, crystal ceiling fixtures light the main body of the room. Windows are screened with wood grilles in Sharaton design.

The Library is finished in knotty pine, both walls and ceiling, in early American style. Wood grilles are fitted at the windows here also, and here continue the effect of the wainscoted walls. Book cases are fitted from floor to ceiling at each end of the room. On the wall on the long side of the room are hung rare old prints of ships of the eighteenth and nineteenth centuries. Drum tables are used in this room, and deep, comfortable arm chairs upholstered in blue morocco. The floor is of deep blue rubber tile, with a thick pile blue carpet runner extending the length of the room. A glass cornice extends entirely around the room, concealing lights, and giving a soft, pleasant illumination well distributed over the whole room.

In the Smoking Room, the walls are wainscoted from floor to ceiling in chestnut stained grayish, with the grain clearly showing. The ceiling is divided into panels by shallow beams of chestnut, and is painted grayish blue. In the center of the room is a well in the ceiling, the sides of which are decorated with panels of undersea life in misty tones, somewhat in the Japanese style. Gray oak is used for the furniture. Table chairs have cane seats and backs, and arm chairs are upholstered in blue leather. The floor is of pinkish gray rubber tile that harmonizes with the walls. Carved wood grilles are fitted at the windows. The walls are decorated with a number of rare prints of old English hunting scenes.

The dance pavilion on "A" deck is a combination of veranda cafe and night club. The room is decorated in the manner of a palm court or covered garden. The walls are of a pale green material of the appearance of stone or marble, and are overlaid with wooden lattice work. Trim is in green, gold, and Chinese red. Living palm trees are used in the decorative scheme. Windows aft and on each side afford light, plenty of fresh air in warm weather, and a fine sea view, and large doors open on a deck aft which forms a quiet open veranda. The center of the room is left clear of furniture, and an excellent maple floor furnishes dancing space for many couples. Outside the dance floor, small tables are placed; and the floor is covered with rubber tile which simulates Travertine marble.

The foyers on "A" deck are furnished with handsome rugs, appropriate furniture of Chippendale design in ebony with champagne colored leather upholstery, console tables, mirrors, and paintings.

The first-class dining saloon is a room of unusual appearance and novel decoration. It is finished in dull silver, relieved by delicate moldings in green. Each wall panel is decorated by a gay bird in bright plumage, and all together form a border of brilliant color around the room. Windows are of leaded "Kapa" shell illuminated artificially from behind and the light from them is soft and iridescent. In the center of the room is a clear story of a full additional deck in height; the walls of this form a marine panorama with ships of all kinds from early Viking types to clipper

ships, including a variety of South Sea sailing craft; with a background of misty headlands suitable to the types of ships. Slender pillars add to the apparent height of this clear story and divide the mural into panels. Illumination is by indirect flood lights. Dining room chairs are made of aluminum, and are finished in dull green with plain upholstery of the same color. The floor is of rubber tile in varying shades of green, and the ceiling is very soft coral pink in diamond shaped panels, with small lights set close to the ceiling and protected by shades of crystal in a pineapple pattern which spread the light without glare.

The interior decoration and furnishing are a distinct departure from the conventional style of steamship decoration. Period rooms are entirely lacking, and heavy hardwood finish has given way to painted walls; and draperies and window curtains to wooden grilles in the public rooms.

In the cabin-class accommodations, the staterooms, foyers, and corridors are decorated in a manner very similar to corresponding first-class spaces. The walls and furniture are painted similarly to walls and furniture of the first-class; and here also coolness, comfort, and simplicity are the keynotes of the decorative schemes.

In the cabin-class, the style of decoration is more conventional, but wicker and light appearing furniture is still retained to a large extent, and the upholstery provides the bright color necessary to relieve the plain paint generally used on the walls. Gay tapestry curtains are used in the windows here. The paint on the walls in staterooms and public spaces is generally ivory and dull green. Fancy decorations are omitted in favor of refined simplicity.

The dining saloon is an especially attractive room, finished in dull green with bright colored curtains at the air ports. The lounge is finished in dull ivory, and the smoking room in small panels of dark oak with large upholstered chairs and oak tables inviting quiet comfort. Both smoking room and lounge have fireplaces with electric logs which add materially to the sense of comfort found in these rooms.

Floors throughout are covered with rubber tile in colors to harmonize with the decorations. Mirrors and pictures are extensively used in appropriate locations.

PROPELLING MACHINERY.

The *Mariposa* is a twin screw installation with high pressure, high temperature boilers, single reduction geared turbines, and is designed for 22,000 total shaft horsepower at 124 R.P.M. of the propellers.

FIRE ROOMS.

There are twelve B. & W. cross drum marine boilers, fitted with interdeck superheaters and tubular air heaters installed in two firerooms, six boilers in each, three abreast.

Total Boiler Water Heating Surface, square feet	53,520
Total Steam Superheating Surface, square feet	5,352
Total Air Heating Surface, square feet	32,112
Steam Pressure at Superheater Outlet, pounds per square inch gage	375
Steam Temperature at Superheater Outlet, degrees Fahrenheit	650

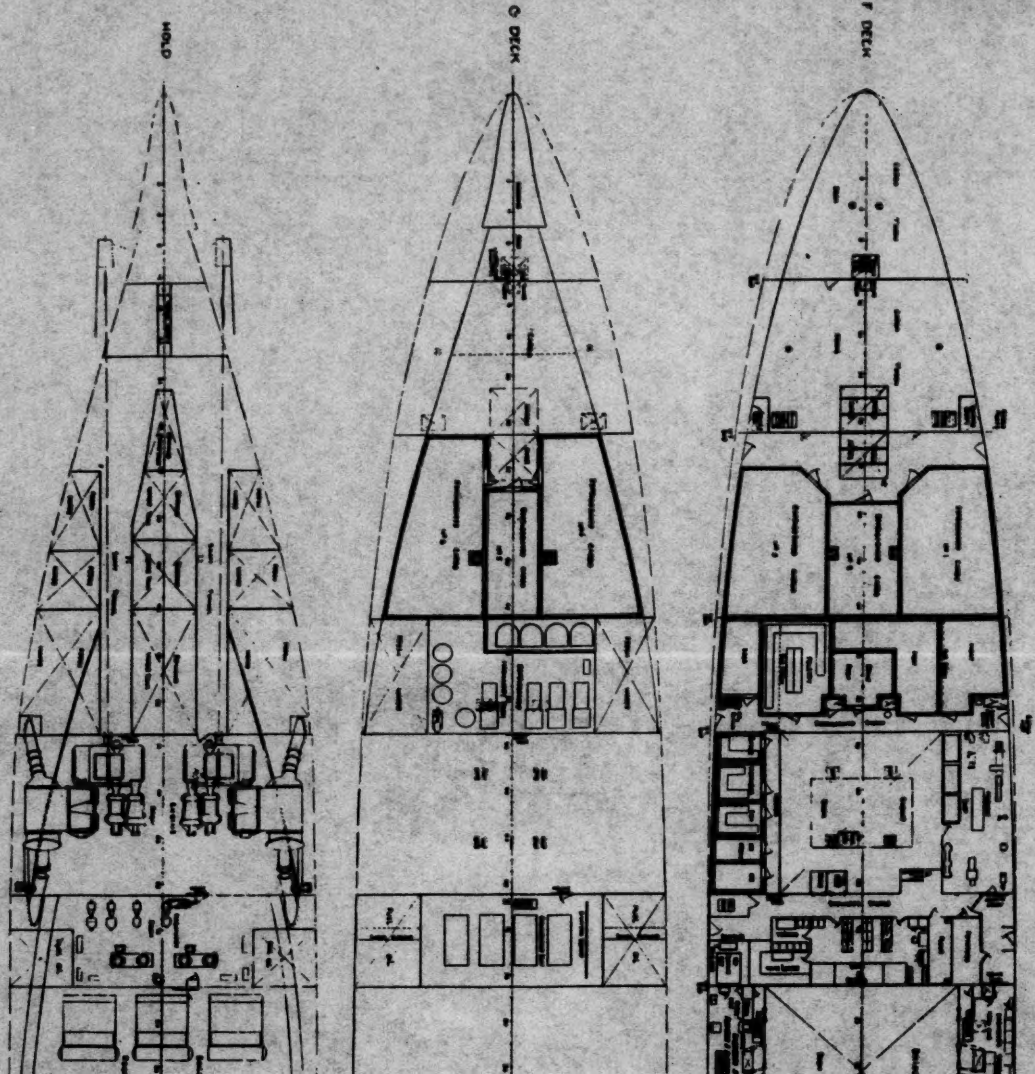
Each boiler is equipped with four Cuyama type B. & W. oil burners, also soot blowers, feed water regulators and smoke indicators.

Closed fireroom forced draft is used with an air pressure of about one inch of water for normal full power conditions. There are four motor driven forced draft blowers in each fireroom (two are spare). They draw the air through ducts leading from the exposed deck and discharge into the fireroom at the working level.

Air for combustion enters the space between the inner and outer breeching casing near the top of the fireroom, flows down and through the air heaters, thence through air casings around and under the boilers, through the double front to the oil burners.

There are two double smokepipes, each of which serves six boilers.

In each fireroom there are two fuel oil service pumps (one spare), one fuel oil transfer pump, an emergency fuel oil service pump, and two fuel oil heaters (one spare).


HOLD
G DECK
F DECK

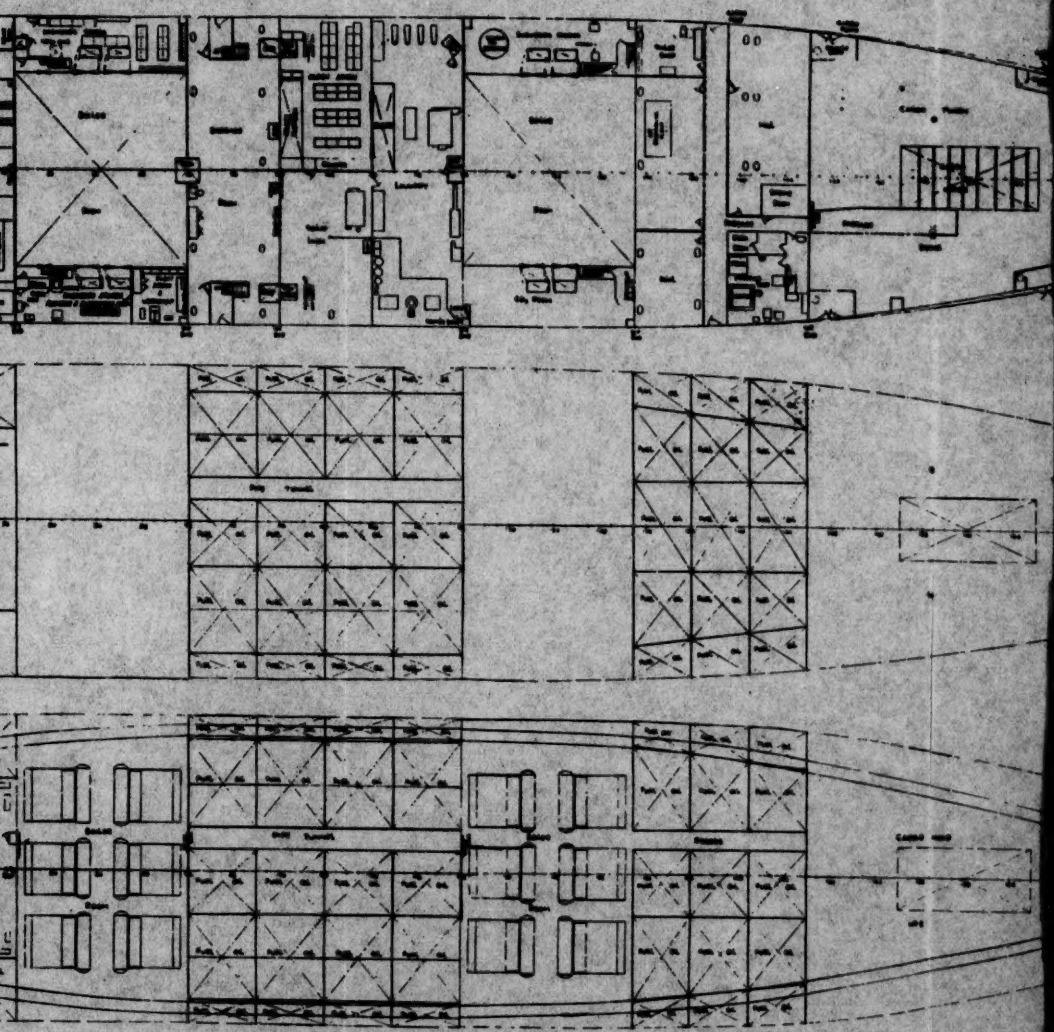


FIG. 1.—DECK PLANS, "F," "G," AND HOLD.

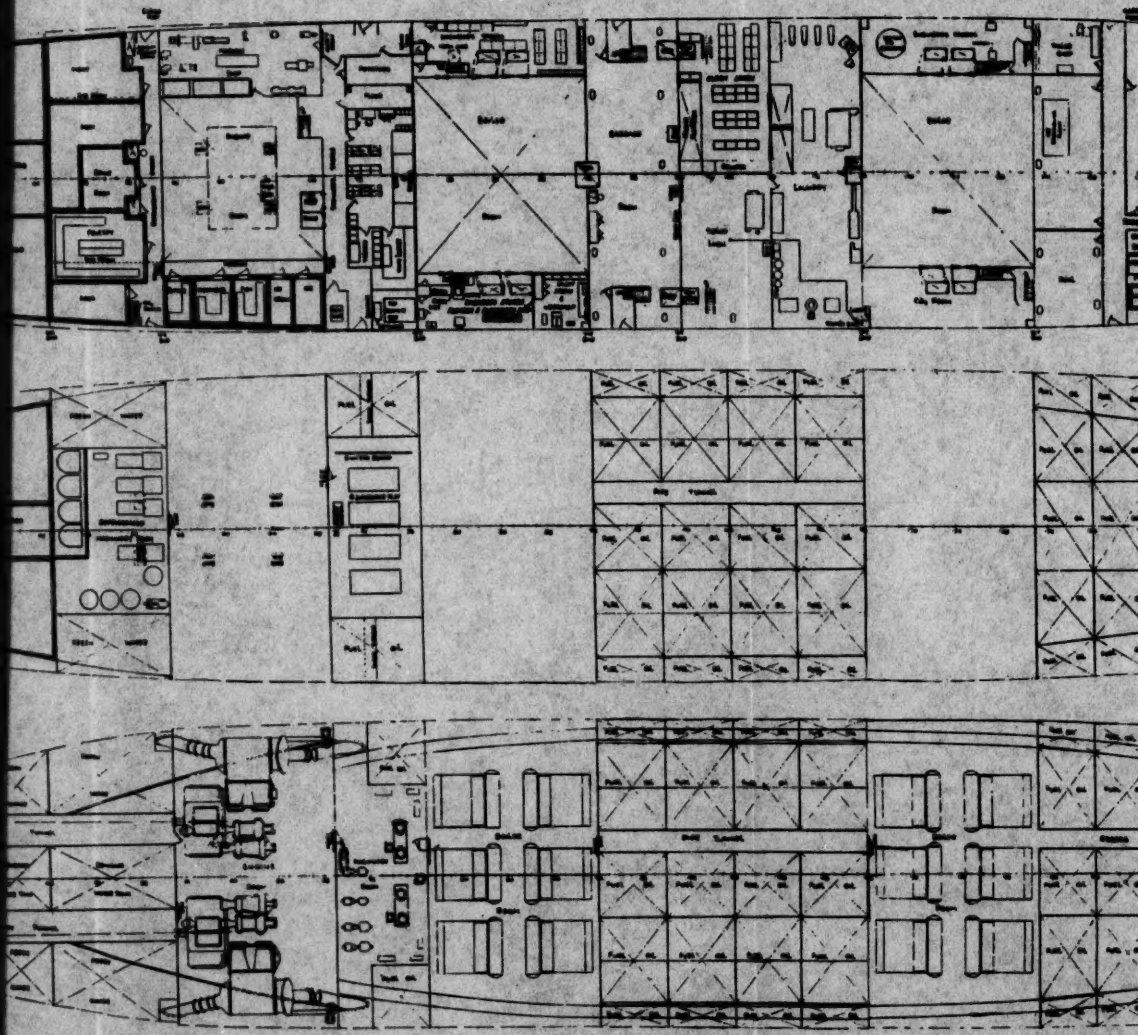
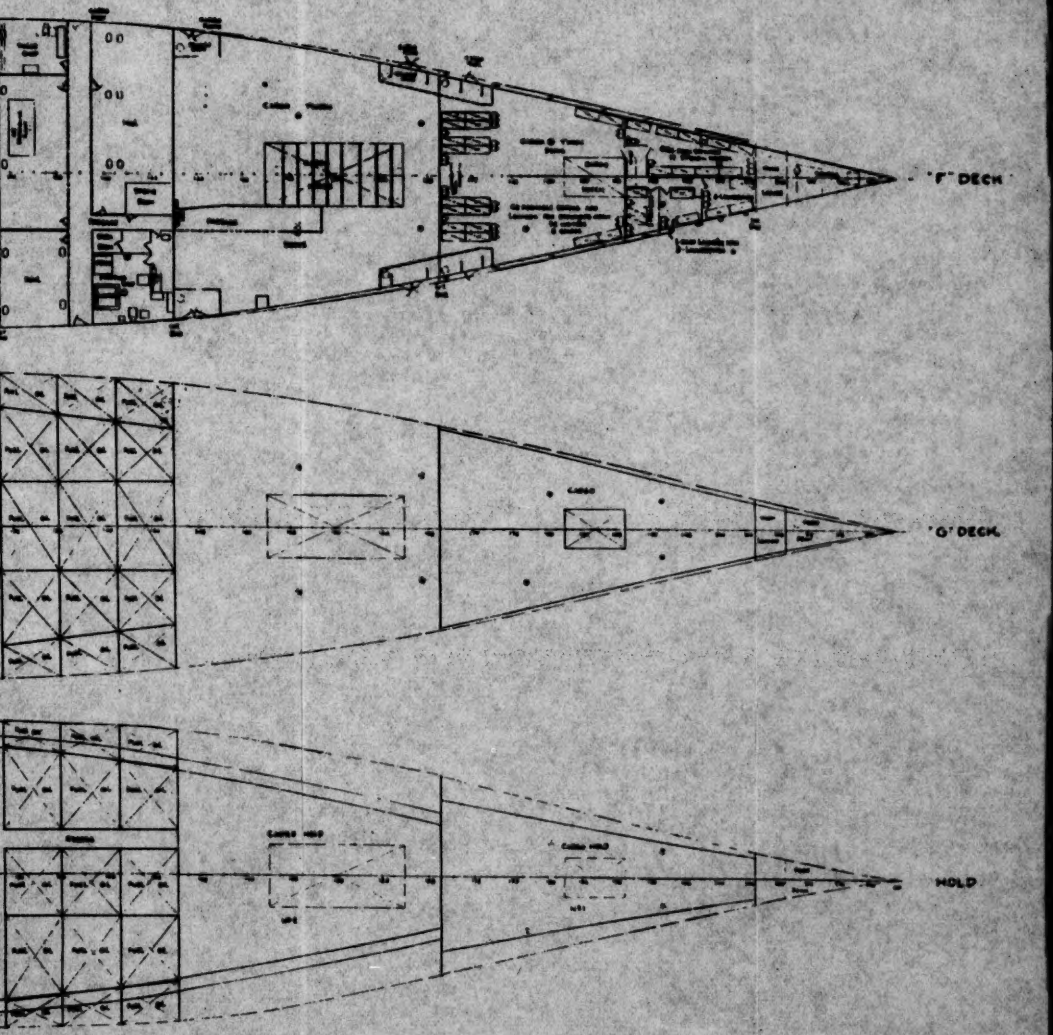
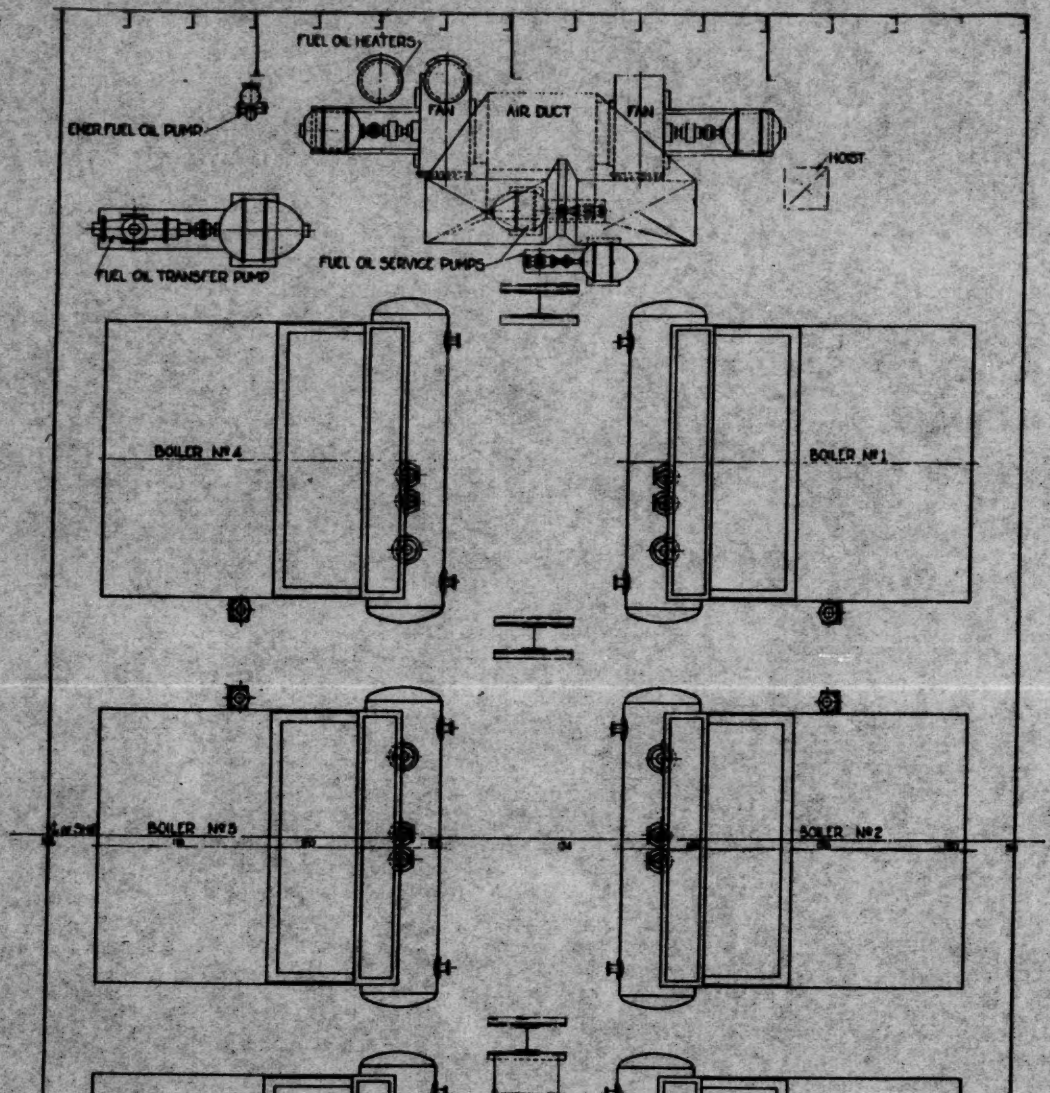
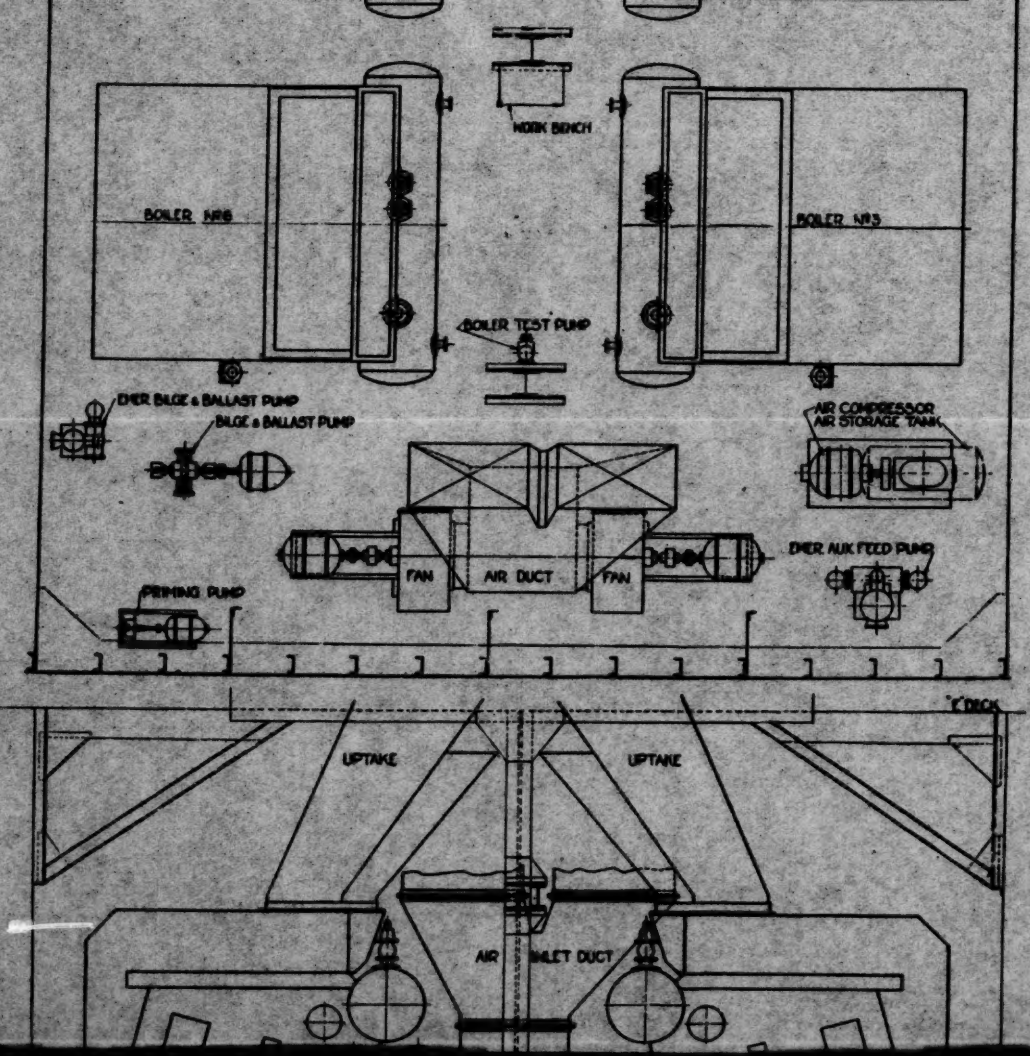
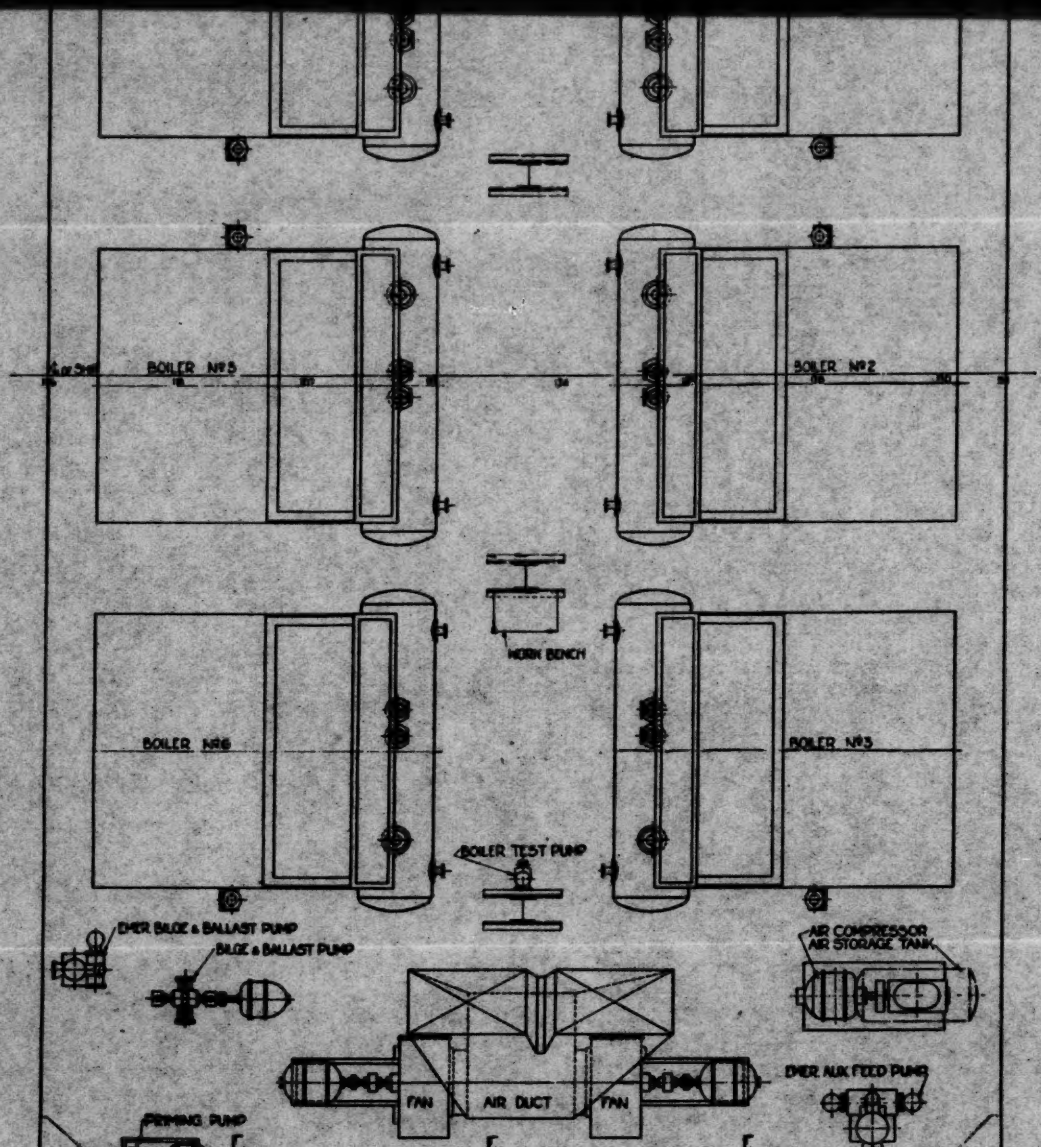


FIG. 1.—DECK PLANS, "F," "G," AND HOLD.


'F' DECK
'G' DECK
HOLD


FUEL OIL HEATERS
FAN
AIR DUCT
FAN
HOIST
EMER FUEL OIL PUMP
FUEL OIL TRANSFER PUMP
FUEL OIL SERVICE PUMPS
BOILER Nº4
BOILER Nº1
BOILER Nº3
BOILER Nº2


WORK BENCH
BOILER NO 6
BOILER NO 5
BOILER TEST PUMP
DIER BILGE & BALLAST PUMP
BILGE & BALLAST PUMP
AIR COMPRESSOR
AIR STORAGE TANK
FAN
AIR DUCT
FAN
DIER AUX FEED PUMP
PRIMING PUMP
'C' DECK
UPTAKE
UPTAKE
AIR INLET DUCT


BOILER Nº5
BOILER Nº2
WORK BENCH
BOILER Nº6
BOILER Nº3
BOILER TEST PUMP
DIFF. BILGE & BALLAST PUMP
BILGE & BALLAST PUMP
AIR COMPRESSOR
AIR STORAGE TANK
FAN
AIR DUCT
FAN
DIFF. AUX FEED PUMP
FEEDING PUMP

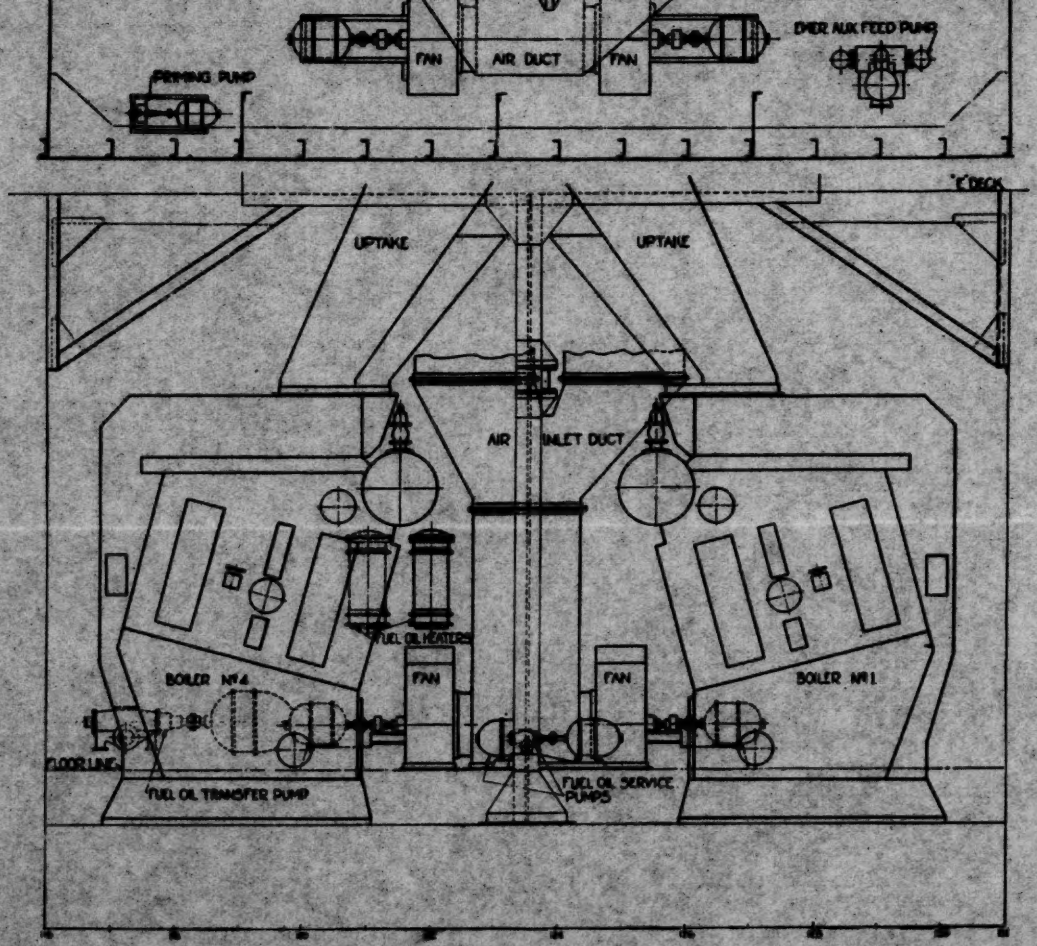
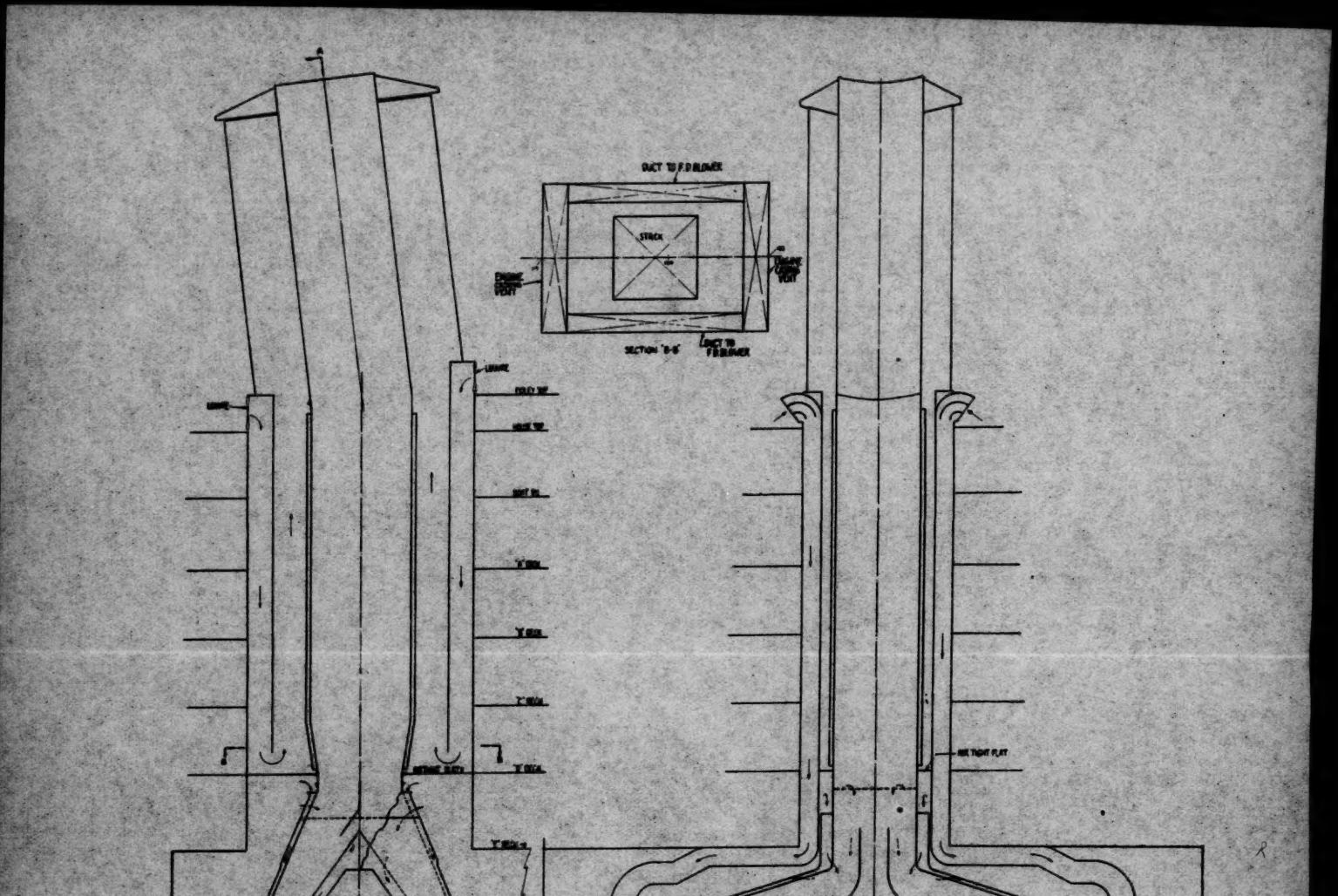


FIG. 2.—PLAN AND ELEVATION OF FIREROOM.


DUCT TO F.D BLOWER
STACK
SECTION 'B-B'
DUCT TO F.D BLOWER
AIR TIGHT PLAT

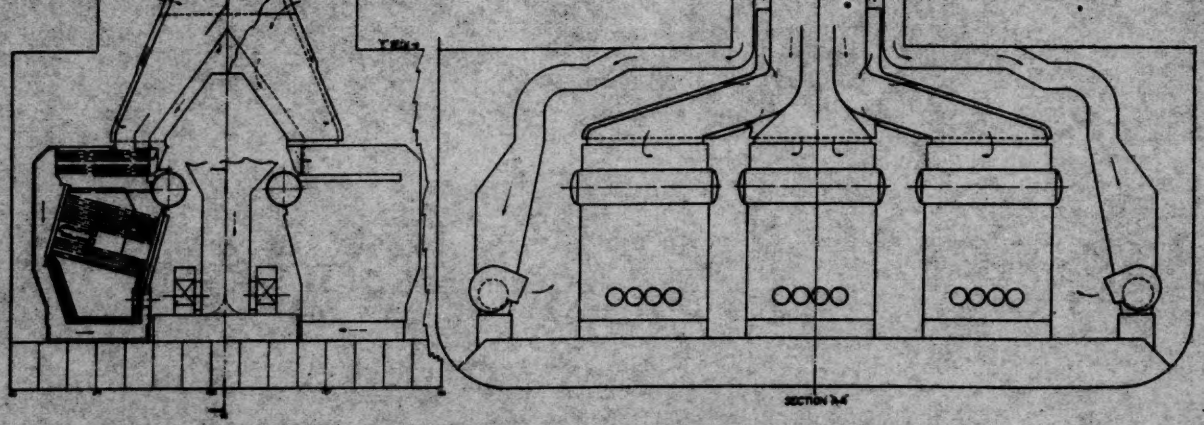
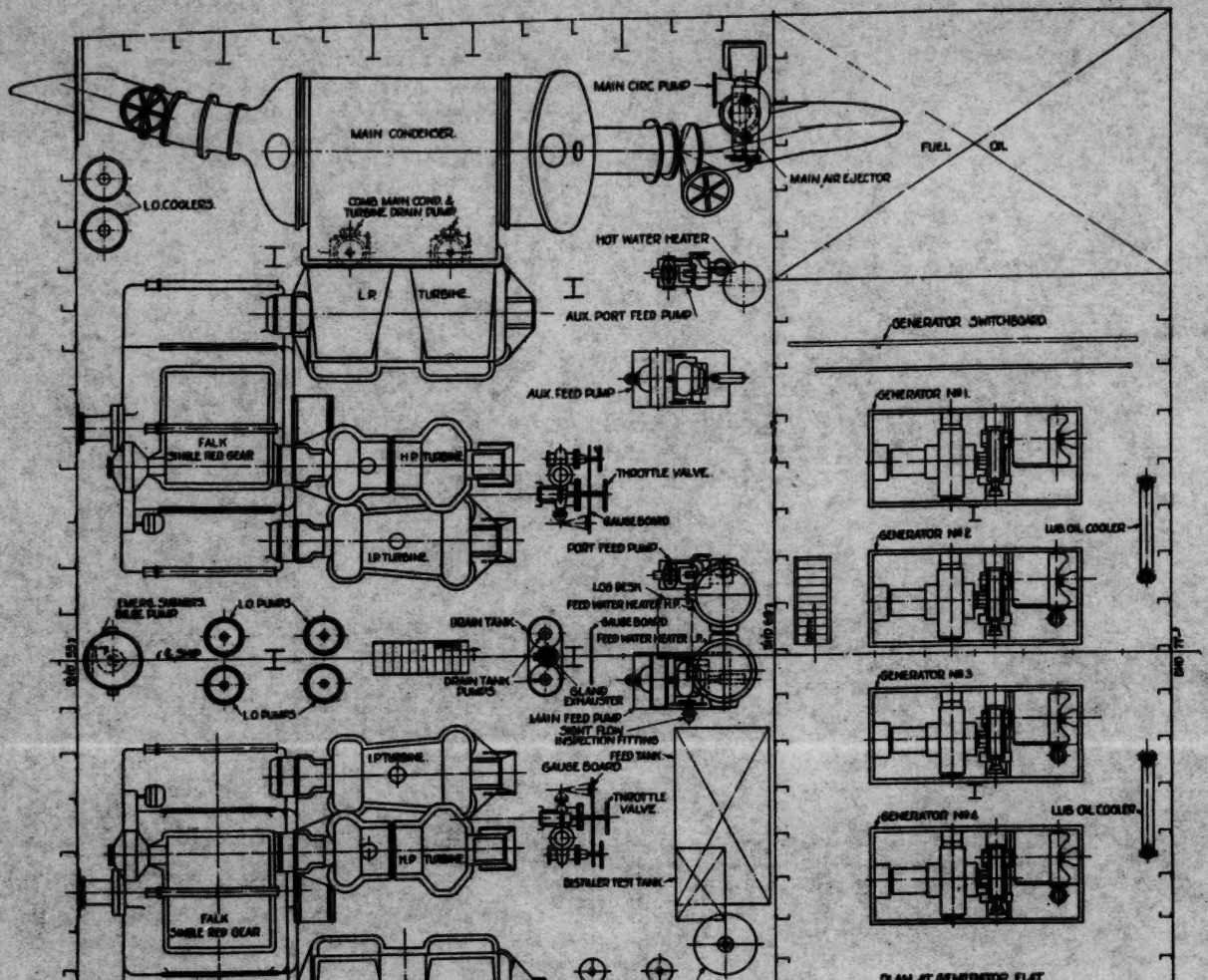


FIG. 3.—ARRANGEMENT OF FORCED DRAFT AND AIR HEATING SYSTEMS.


MAIN CIRC. PUMP
MAIN CONDENSER
FUEL
OIL
MAIN AIR EJECTOR
L.O. COOLERS
COMB. MAIN COND. & TURBINE DRAIN PUMP
HOT WATER HEATER
L.P. TURBINE
AUX. PORT FEED PUMP
GENERATOR SWITCHBOARD
AUX. FEED PUMP
GENERATOR No 1
FALK SINGLE RED GEAR
H.P. TURBINE
THROTTLE VALVE
GAUGE BOARD
L.P. TURBINE
PORT FEED PUMP
GENERATOR No 2
LUB OIL COOLER
EMERG. SUBMERS. BILGE PUMP
L.O. PUMPS
L.O. PUMPS
DRAIN TANK
LOG DESH
FEED WATER HEATER H.P.
GAUGE BOARD
FEED WATER HEATER L.P.
DRAIN TANK PUMPS
GLAND EXHAUSTER
GENERATOR No 3
MAIN FEED PUMP
SMART FLOW INSPECTION FITTING
FEED TANK
L.P. TURBINE
GAUGE BOARD
THROTTLE VALVE
GENERATOR No 4
LUB OIL COOLER
H.P. TURBINE
DISTILLER TEST TANK
FALK SINGLE RED GEAR
PLAN AT GENERATOR FLAT

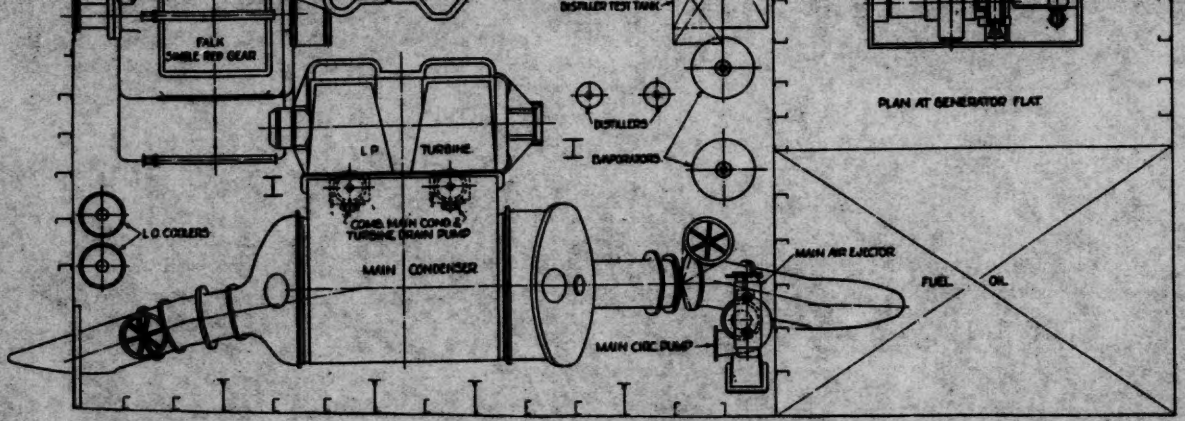
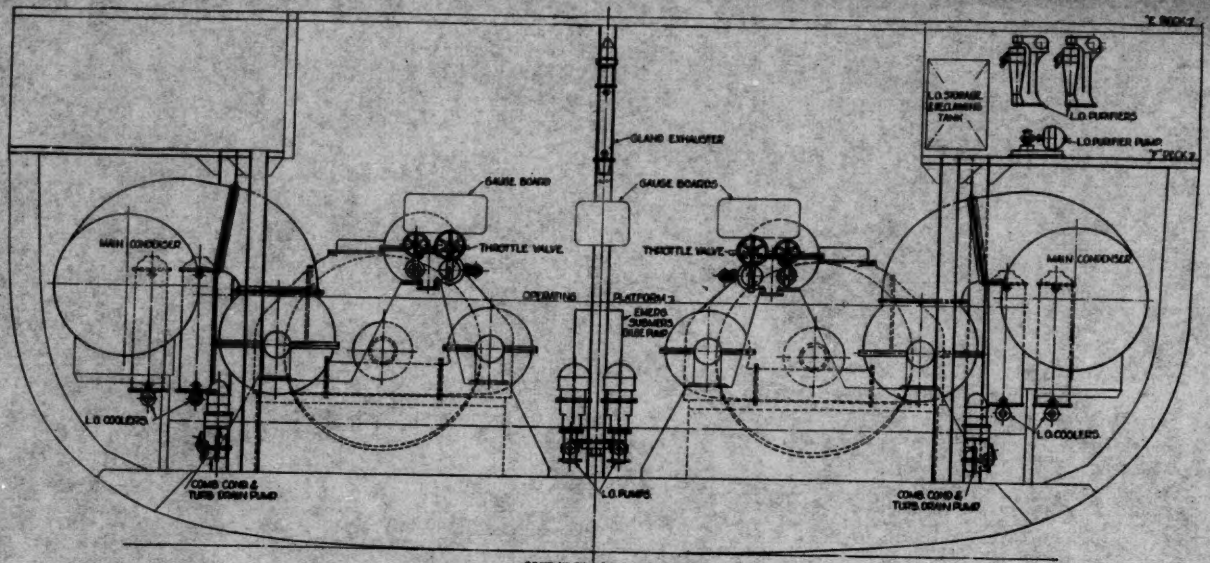


FIG. 4.—PLAN OF ENGINE ROOM.



SECT. AT FR 66 - LOOKING AFT.

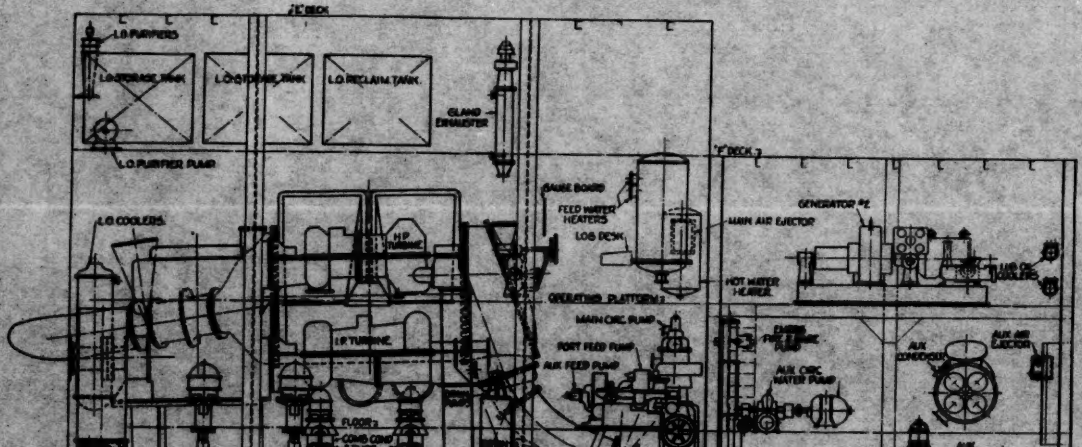
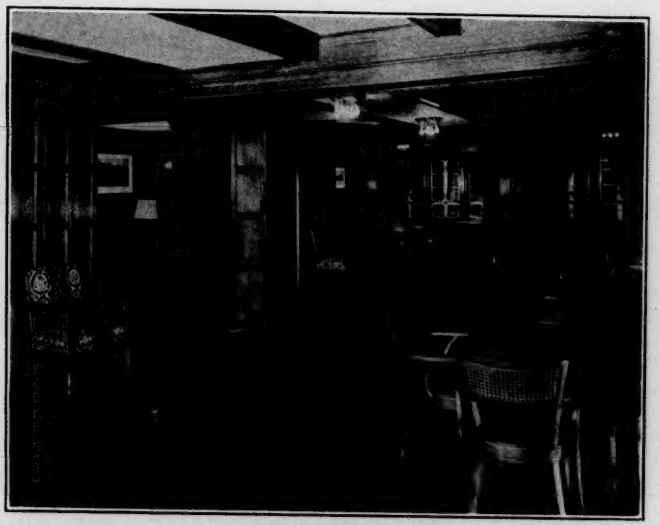


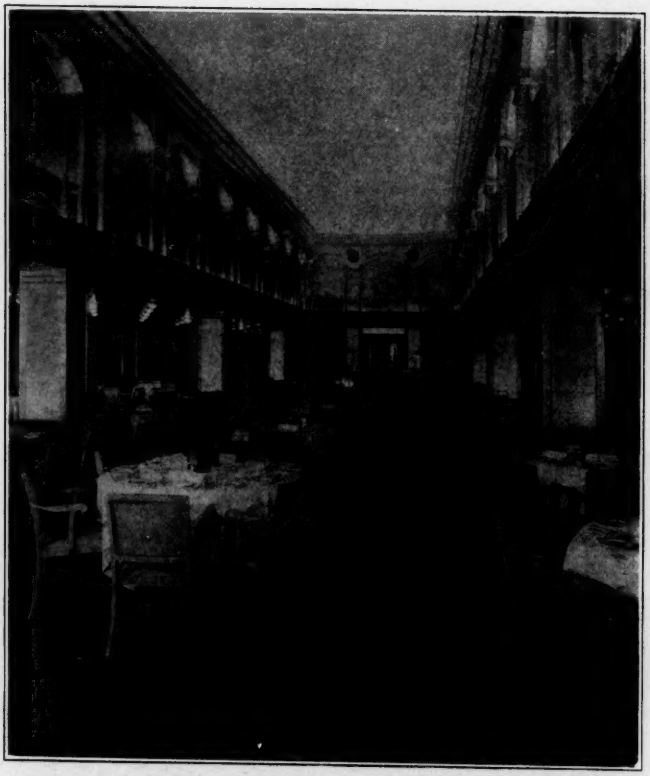
FIG. 5.—ELEVATION OF ENGINE ROOM.



CABIN SMOKING ROOM.

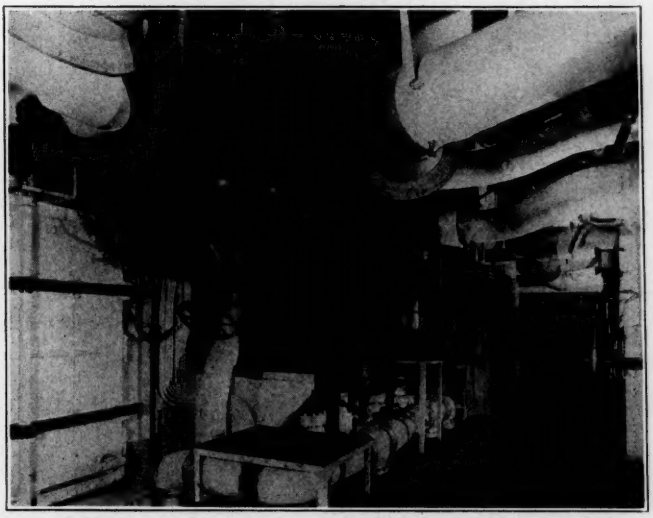
Photos by Technology Photographic Service.

FIRST-CLASS LOUNGE.

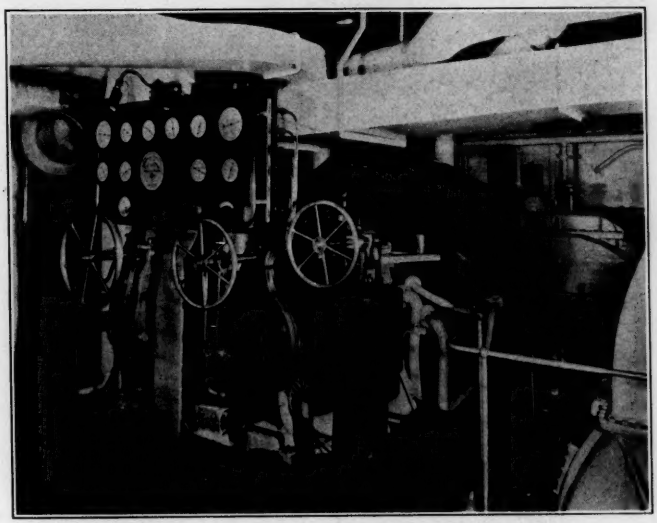


Photos by Technology Photographic Service.

FIRST-CLASS DINING SALOON.

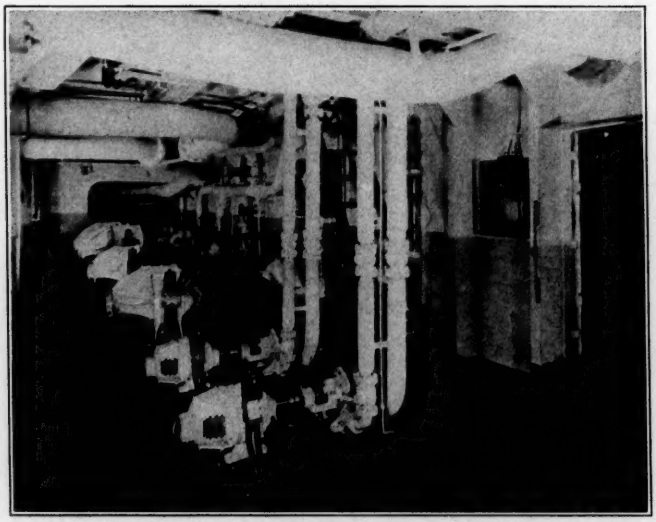


MAIN HANDLING PLATFORM—FORWARD SIDE—MAIN STOP VALVES IN FOREGROUND.

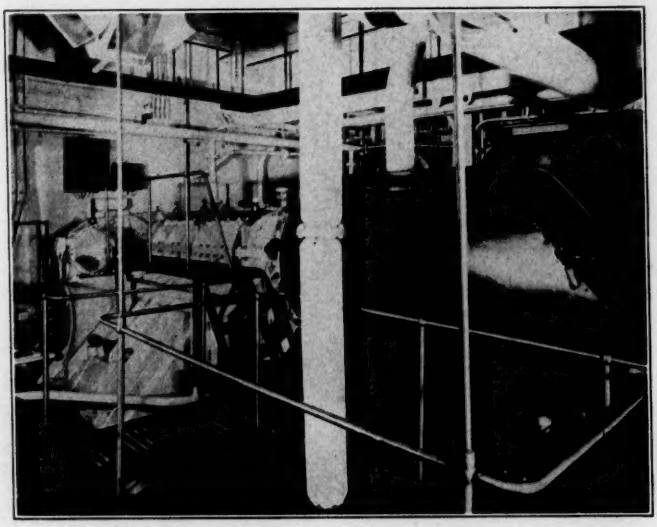


Photos by Technology Photographic Service.

MAIN ENGINE ROOM—CONTROL STATION FOR PORT ENGINES, SHOWING TURBINES AND GEAR IN BACKGROUND.

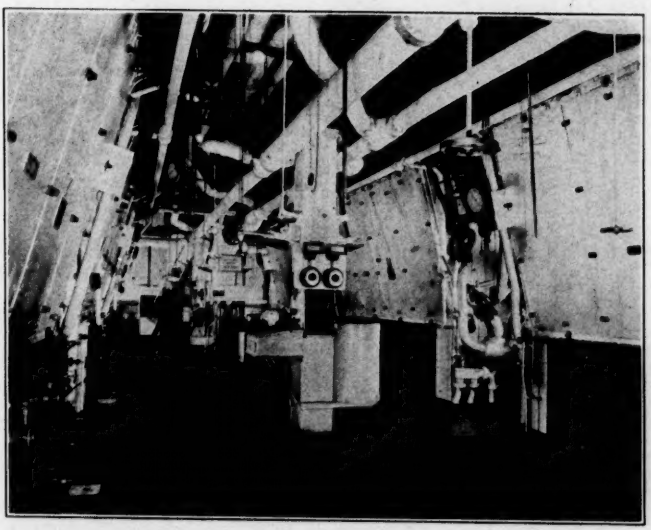


AUXILIARY MACHINERY ROOM—LOWER LEVEL.



Photos by Technology Photographic Service.

MAIN ENGINES—PORT HIGH PRESSURE TURBINE, TOP OF REDUCTION GEAR, AND TURNING MOTOR.



Photos by Technology Photographic Service.

NUMBER TWO BOILER ROOM.

ENGINE ROOMS.

Each set of turbines consists of three Bethlehem-Parsons turbines in series, in separate casings around a single gear wheel.

The H.P. turbine is of the impulse-reaction type with a dummy piston forward of the impulse wheel. The I.P. and L.P. turbines are of the reaction type, the former being single and the latter double flow. The astern turbine is located in the forward end of the L.P. turbine and is a two-stage impulse turbine. The first stage has three moving rows of buckets and the second stage two moving rows. The designed steam conditions are 360 pounds per square inch gage and 650 degrees F. temperature at the throttle, and 28½ inches vacuum at the exhaust flange of the L.P. turbine.

Steam is admitted to the H.P. turbine through 29 nozzles, 15 of which are always open, and the remainder controlled by hand nozzles in three groups of 2, 4 and 8 nozzles respectively. An oil controlled overspeed governor is fitted.

Gears are of the single reduction, double helical type manufactured by the Falk Corporation. The propeller thrust is taken by a 34-inch Kingbury pivoted segmental type of thrust bearing installed in the forward end of the gear casing. Thirteen-and-a-half-inch bearings of the same type are fitted on the forward end of each turbine shaft.

The propellers are solid manganese bronze with streamline blades. They are 18 feet 0 inches in diameter and 19 feet 6 inches pitch. Developed area 105.8 square feet; projected area 88.7 square feet.

Located outboard of the low pressure turbines and connected thereto by double exhaust trunks are two Bethlehem main condensers of the single pass type, each with a cooling surface of 13,562 square feet. These condensers are served by injection scoops. For maneuvering and stand-by conditions, vertical turbine-driven propeller type circulating pumps are provided, one for each main condenser.

Each condenser is provided with a twin two-stage air ejector mounted on a combined inter- and after-condenser. Each two-

stage unit has sufficient capacity to remove the air from condenser it serves when the unit is developing maximum power. The other set is used as a standby.

Two vertical motor-driven centrifugal main condensate pumps are provided for each unit, one being a standby pump. On the end of the condensate pump shaft and contained in the same casing there is provided a turbine drain pump.

There are four Westinghouse 500-Kw., 240/120-volt D.C. geared turbo-generators, 6000-1200 R.P.M., with external balance coils; each generator is capable of 25 per cent overload. The turbines are of the high-speed, high-efficiency type. The turbines of the two inner generators are arranged for emergency atmospheric exhaust.

There are two 3400-square foot Bethlehem two-pass straight tube condensers serving the four turbo-generators. One 10-inch horizontal single stage centrifugal circulating pump is provided for each condenser. There is a twin two-stage air ejector mounted on a combined inter- and after-condenser for each condenser. One two-stage unit is sufficiently large to remove the air from the condenser it serves at maximum power, the other being a standby.

All air ejector inter- and after-condensers are cooled by condensate only. A recirculating connection is provided from the discharge side of the air ejector condenser to the condenser unit it serves, to provide sufficient cooling water under emergency conditions.

The main switchboard consists of 10 panels and is about 22 feet long. The power bus is 230 volts and the lighting bus 230/115 volts with a grounded neutral. All circuit breakers providing power to auxiliaries have the time-delay feature, and breakers supplying the galleys have under-voltage trips.

There are a total of 46 electric stations throughout the boat for the distribution of power and lighting. Some are for power, some are for lighting, and some are for both. Power feeders for these stations are run direct from the main switchboard. Duplicate 6-wire lighting feeders, for all but machinery compartments, are run direct from the forward and aft lighting distribution boards, one-half the load connected to each feeder. The lighting for the

various machinery compartments is fed direct from the main switchboard to individual panels in each compartment.

The total connected power load is 2600 Kw. and the total lighting load is 230 Kw.

The emergency power and lighting plant consists of a 30-Kw., 115-volt D.C. Diesel engine-driven generating set and a 60-cell, 310-A.H. storage battery. If the main generating plant fails, the emergency lights are automatically switched over to the storage battery, which has power available to supply the radio equipment and emergency lights for a period of about 2 hours.

All motors are designed for 110 per cent continuous rating in order to operate satisfactorily in the Tropics. There is a total of 235 motors ranging in size from ¼ horsepower to 75 horsepower, the aggregate of which is 2500 horsepower.

Wherever possible open-type control equipment has been used and this has been assembled on special panels to form group control switchboards at the various electric stations. All control equipment is semi-automatic with remote control pushbuttons at the motors. On all vital auxiliaries in the machinery spaces indicator lights have been provided over the gage boards to show the operation of the auxiliary.

There are twenty watertight sliding doors below the bulkhead deck, electrically operated by the Cutler-Hammer system which consists of motors and control equipment at each door and master controls in the wheel house. Provision is made to open or close these doors either singly or all at once from the master control. Mechanical control is also provided at each door from stations above the bulkhead deck. An electrical indicating system shows the position of each door, at each mechanical control station. Safety gates which close before the main door operates are provided in all passages through which passengers may pass.

There are two Henschel telephone systems, one for use in navigating the ship with telephones located in the wheel house, engine room, steering engine room, crow's nest, forecastle deck, and aft docking station, the other for the use of the engineering force, with telephones located in the engine room, chief engineer's stateroom, chief engineer's office and each fire room.

There is also provided a complete telephone system for the use of the passengers and ship's personnel. This is a standard American Telephone and Telegraph Company installation, consisting of a 400-line, 1-position switchboard and telephones in each passenger's and officer's stateroom. Shore connections are provided to enable calls to be put through the local exchange while the ship is docked.

All auxiliary turbines take steam at full boiler pressure and full temperature, and exhaust against a back pressure of 10 pounds, with the exception of the turbo-generators which exhaust into a condenser at 28.5 inches vacuum.

The emergency steam-driven reciprocating pumps take steam at full pressure, which has passed through the desuperheaters in the four centerline boilers.

All motor-driven auxiliaries are equipped with Westinghouse motors and control equipment.

The evaporating plant consists of two evaporators with automatic feed regulators, two distillers and the necessary inter-connecting piping. It is normally used for pre-evaporating raw fresh water for makeup feed pump supply. Operating steam is supplied from the high pressure bleeder line and the vapor discharged to the low pressure bleeder line. Distilled fresh water is thus provided at a minimum cost in fuel. Connections are fitted to permit distillation of sea water in an emergency. Provision is also made for operation from a reduced pressure line.

There are four Brunswick-Kroeschell CO_2 refrigerating units, with a capacity of 15 tons per day, for cooling cargo, ship's stores and conditioning the air in the dining saloon.

A complete list of the machinery is given in the tables "Machinery List."

TRIALS.

The Standardization trial was held on the Rockland, Me., Course, December 10, 1931, and was followed by a 12-hour, Full Power and Fuel Consumption Trial.

The following is the average data for the trials:

MACHINERY LIST.

No.	Unit	Type	Rating	Particulars	Vendor
2 sets	Main Turbine	Triple Cyl. HP Ahead Turb., Impulse Reaction IP Ahead Turb., Reaction LP Ahead Turb., Reaction Double Flow Astern Turb., Impulse (Located in LP Turbine Casings)	SHP (Max.) - 25,000 SHP (Power Trial) 22,000 @ 117.8 RPM W.R. - 8#/SHP/Hr. @ 22,000 SHP Stm. Press.- 375# (G.) " Temp. - 650° F. Vac. - 28.5" Hg.	HP) IP) 1500 RPM LP) Thrust Brg. - 13-1/2" 3-Shoe Type	Beth. Ship
2	Reduction Gears	Single Reduction Double Helical 3 Pinion 2 Plane	Pinions / Gear RPM: HP) / IP) 1500 / 117.8 / LP) P.D 12.25" / 156" Net Face 56" / 56"	Main Thrust Brg. 34" DH Kingsbury No. Shoes - 6 Location - In For'd End of Gear	Falk Corp.
2	Turning Gear	On HP Pinion	Ratio - 297 to 1 HP - Motor - 8.5 @ 600 RPM		Falk Corp. Motor - Westinghouse
2	Main Condensers	Sing. Pass. Straight Tube Scoop injection	Cap.-181,842 #/Hr.Stm. Vac.-28.5 Hg. Circ. W.- 15,000 GPM @ 70° F. Scoop Dia. - 32"	Cool.Surf.15,562 Sq.Ft. No. Tubes - 5,526 Dia. " -3/4" O.D. Thickness of Tubes - # 16 BWG Lgth.Bet.Tube Sheets 12'-6"	Beth. Ship (Tubes packed at outlet ends. Packing - #72 Corset Lacing)
2	Dynamo Condensers	Two-Pass Straight Tube	Cap. - 14,200 #/Hr.Stm. Vac. - 28.5" Hg. Circ. W.-2,200 GPM @ 70° F.	Cool.Surf.-3,400 Sq.Ft. No.of Tubes - 1922 Dia. " - 3/4" O.D. Thickness of Tubes - # 17 BWG Lgth.Bet.Tube Sheets 9'-0"	Beth. Ship (Tubes packed at outlet ends. Packing -#72 Corset Lacking)
12	Boilers	Water Tube Cross Drum Oil Burning-Air Htrs. Inter-Deck Suphtrs. F.W. Regulators (De-superheaters for 4 Middle Boilers only) "Cuyama" Burners	Tot.Stm.Gen.Cap. - 250,000 # per Hr. Stm.Press.- 375# (G.) Supht. - 200° F.	Tot.Htg.Surf.-53,520 Sq. Ft. Tot.Suphtg. Surf.- 5,382 Sq. Ft. Tot. Air Htg. Surf.- 32,112 Sq. Ft.	B & W Co. (Closed Fireroom. 2 safety valves. Size Inlet - 5½" Outlet - 4" Setting - 400#)
2	Main Circ.Pumps	18" Vert. Sing.Stg. End Suct.- Turb. Driven	Cap.- 8000 GPM @ 25' Hd Turb. HP -68 @ 1150 RPM	W.R.-70.5#/BHP/Hr.@ 1150 RPM Stm.Press. - 360 # Steam Temp. - 600° F.	Warren-Pump Sturt.-Turb. (Speed Governors & Water Cooled Ring Oil Brgs.)
2	Dynamo Circ. Pumps	10"Hor.Cent. 1 Stg. 10 - DM - 12	Cap.- 2500 GPM @ 20' Hd 17 HP Motor @ 1150 RPM		Warren-Pump Westg.- Motor

		Driven		Stm.Press. - 360 # Steam Temp. - 600° F.	(Speed Governors & Water Cooled Ring Oil Brgs.)
2	Dynamo Circ. Pumps	10"Hor.Cent. 1 Stg. 10 - DM - 12 Suct. 12" Disch. 10"	Cap.- 2500 GPM @ 20' Hd 17 HP Motor @ 1150 RPM		Warren-Pump Westg.- Motor
4	Combined Main Condensate and Turb. Drain Pumps	Vert.1Stg.Centrif. Turb. Drain: Disch.2" Suct.2-½" Condensate: Disch.3½" Suct. 8"	Mn.Cond. Pump: 225 GPM @ 70' Hd. Turb. Drain Pump: 20 GPM @ 10' Hd. Mn.Cond. P.Motor: 10 HP @ 1150 RPM		Warren-Pump Westg.-Motor
3	Dynamo Condensate Pumps	2"Vert.Cent.- 1 Stg. Suct. 4" Disch. 2"	Cap.- 40 GPM @ 60' Hd. 3 HP Motor @ 1750 RPM		Warren-Pump Westg.-Motor
1 1	Main Feed Pump Aux. Feed Pump	5"Hor.Cent.- 3 Stg. Turb. Driven 5-BFK - 20 6" Disch. 6" Suct.	Cap. - 550 GPM Disch.Press. 450# Turb. HP-250 @ 2750 RPM Turb.W.R.-33.5#/BHP/Hr. Turb. Back Press. - 10#	Stm.Press. -360# " Temp. - 600° F.	Warren-Pump Sturt.- "C-12" Turb.
1 1	Feed Pumps: Port Boiler Aux.Port Boiler	Hor.Cent. - 1 Stg. Turb. Driven Close Coupled Suct. - 3" Disch. - 2½"	Cap.-100 GPM @ 1040' Hd. RPM - 6000 Stm.Consump -1750#/Hr. " Press. - 360# " Temp. - 650° F. Exh.Back Press. 10#	WR - 29# BHP/Hr. BHP - 58.5	DeLaval
2	Emerg. Aux. Feed Pumps	12" x 8" x 18" VSDA	Disch.Press. - 450# Stm. Press. - 360# Superht.- 50° F.		Warren
2	Fire & San. Pump	Hor. Cent. - 2 Stg. 4 - 2H - 14 Disch. - 4" Suct. - 5"	Cap.-500 GPM @ 280' Hd. 54 HP - Motor @ 1750 RPM		Warren-Pump Westg.- Motor
2	Emerg.Fire and Bilge Pump	8" x 10" x 24" VSDA	Disch.Press. - 125# Stm. Press. - 360# Superht. - 50° F.		Warren
2	Hand Fire Pumps	Double Acting 3" Disch 3" Suct.	Cap.- 107 Cu.In.Piston Displacement per Rev. Suct. Lift - 15 Ft. Disch. Hd. - 100 Ft.		Ramsey Co.

No.	Unit	Type	Rating	Particulars	Vendor
2	Bilge & Ballast Pumps	5" Hor. Cent. 1 Stg. Disch. 5" Suct. 6"	Cap.-700 GPM @ 50' Hd. 15 HP Motor @ 1150 RPM	Connected to Priming Pumps	Warren-Pump Westg.- Motor
1	Emerg.Bilge Pump	Vert. Cent. 1 Stg. (Submersible Type) Disch - 4" Suct. - 5"	Cap. 700 GPM @ 40' Hd. 15 HP Motor @ 1150 RPM	Motor Enclosed in Water Tight Bell	Warren-Pump Westgh.-Motor
4	Lub. Oil Pumps	#5 Gear-in-head Vert. Screw Type Motor Driven 4" Disch. 5" Suct.	Cap.-300 GPM @ 80' Hd. 15 HP Motor @ 1200 RPM		Quimby-Pump Westg.- Motor
1	Lub. Oil Purif. Pumps	Series 4EY Motor Driven Disch. - 3/4" Suct. - 1"	Cap.- 6 GPM @ 20' Hd. 3' Suct.Lift @ 60° F. 1 HP Motor @ 1200 RPM		Northern-Pump Westg.- Motor
2	Emerg.Fuel Oil Serv. Pumps	5½x5-1/2"x12" VSDA	Disch. Press.- 250# Stm. Press.- 360# Supht.- 50° F.		Warren
2	Fuel Oil Transf. Pumps	#7 Hor.Gear-in-Head Screw Type - Motor Driven Disch. - 6" Suct. - 8"	Cap.-600 GPM @ 125' Hd. 75 HP Motor @ 450-900 RPM 15° Baume F.O.@ 60° F. Suct.Lift (Primed)20 Ft.	Connected to Priming Pumps	Quimby-Pump Westg.-Motor
4	Fuel Oil Serv. Pumps	#2-1/2 Hor. Heavy Duty,Gear-in-Head Motor Driven Disch.- 1-1/2" Suct.- 2-1/2"	Cap. - 30 GPM @ 250# 7½ HP Motor @ 600/ 1200 RPM. Suction Lift-20 Ft. @ 60° F.	Variable Speed	Quimby-Pump Westg.-Motor
2	Drinking Water Pumps	Hor.Cent.- 1 Stg. Motor Driven 1-1/2 DB-11 Disch.- 1-1/2" Suct.- 2"	60 GPM @ 170' Hd. 7½ HP Motor @ 2200 RPM		Warren-Pump Westg.- Motor
2	Fresh Water Pumps(Washing)	Hor.Cent.- 1 Stg. Motor Driven 2-DB-13 Disch.- 2" Suct.- 3"	Cap.-150 GPM @ 170' Hd. 15 HP Motor @ 1980 RPM		Warren-Pump Westg.-Motor
4	Ice & Hot Water Pumps	Hor.Cent.- 1 Stg. Motor Driven 1-1/2-DB-11 Disch.- 1-1/2" Suct.- 2"	Cap.-60 GPM @ 170' Hd. 7½ HP Motor @ 2200 RPM		Warren-Pump Westg.-Motor
2	Priming Pumps For B & B, F.O. Trans. & F.W. Pumps	Nash Hytor Vac. Pump - 1 Stg. Motor Driven Disch.) 1-1/4"	Cap.-37CFM @ 10"Hg.Vac. 3 HP Motor @ 1750 RPM		Nash-Pump Westg.-Motor

		Suct.- 2"			
2	Priming Pumps For B & B, F.O. Trans. & F.W. Pumps	Nash Hytor Vac. Pump - 1 Stg. Motor Driven Disch.) 1-1/4" Suct.)	Cap.-37CFM @ 10"Hg.Vac. 3 HP Motor @ 1750 RPM		Nash-Pump Westg.-Motor
2	Boiler Test Pumps	4½"x 2½"x 6" VSDA	Disch. Press.- 600 # Stm. Press.- 360# Superht.- 50° F.		Warren
2	Sump Pumps	Vert.Cent.- 1 Stg. Submerged Motor Driven Size 1-1/2	Cap. 25 GPM Hot Water @ 200-212° F.		Gould- Pumps Westg.-Motor
2	CO_2 Condenser Circ.Pumps	Hor.Cent.-1 Stg. Motor Driven Disch - 4" Suct.- 5"	Cap.400 GPM @ 50' Hd. 7½ HP Motor @ 875/1150 RPM		Warren- Pump Westg.-Motor
3	Cargo Brine Pumps	Hor.Cent.- 1 Stg. Motor Driven Disch.- 2" Suct.- 3"	Cap.210 GPM @ 60' Hd. 7½ HP Motor @ 1750 RPM		Warren- Pump Westg.- Motor
1	Ship's Stores Brine Pump	Hor.Cent.- 1 Stg. Motor Driven Disch.- 2" Suct. - 1-1/2"	Cap. 25 GPM @ 120' Hd. 5 HP Motor @ 1800 RPM		Warren - Pump Westg. - Motor
2	Rotary Hand Pumps	#3 Semi-Rotary #661 - Dbl. Acting	Suct. Lift - 10 Ft. Disch. Hd. - 10 Ft.		Rumsey Pump Co.
4	500 KW Generators	Geared Turb. 230 Volt D.C.	Turb. RPM 6000 Gen. RPM 1200 Turb. W.R./Full Load- 14.5#/KW/Hr. Stm. Press. - 350# Stm. Temp.- 550° F. Condsr.Vac.- 28.5" Hg.	Two Inner Generators arranged for Emergency Non-Condensing as well as for Normal Condsr.Operation	Westinghouse
1	Emergency 30KW Generator	Diesel Driven D.C.- 120 Volts Direct Connected	Eng. HP - 45 No. Cyl. - 3 Dia. Bore -8-1/2" Stroke - 8-1/2"		Westg.- Gen. Atlas - Diesel

No.	Unit	Type	Rating	Particulars	Vendor
1	Air Compressor for Emergency 30 K.W.Generator		Cap.Air Comp.-5 cu.ft. per min. RPM Air Comp. - 450 HP Motor - 1 No. Cyl. - 2 Dia. Bore - 1-1/2" (HP) " " - 2" (LP) Stroke - 3" Disch. Press.- 250#	Air Tanks - 18"x36"	Supplied with Gen. Westghse. Motor
	Windless	Horizontal 2 - Wildcats 2 - Gypsies 2 - D.C. Motors 50 HP 600 RPM 230 V. Comp. Wound	Wildcat - 2.93 RPM Wildcat - 30 F.P.M. Gypsy - 14.7 RPM Gypsy - 30 F.P.M. Total Red.- 205 to 1 Spur-Geared	3-1/8" Stud Link Anchor Chain 30 Fathoms	Beth. Ship Westghse. Motors
1	Refrig. Plant:- 4 - CO_2 Compressors 4 Condensers 4 Evaporators 1 Liquid Receiver 4 Oil Traps 4 Suct. Traps 1 CO_2 Dryer 1 Ice Making Set 1 Scuttlebutt 1 Brine Return Tank 1 Cage Board	Vert. 2 Cyl. "M-2" Single Acting Forced Lubrication 5/4" ID - 1" OD Tubing	Cap.-14 Tons/24 Hrs. Suct.Gas.Temp. Minus 10° F. Cond. Water - 85° F. HP Comp. Motor - 66 RPM - 320 2330 Ft. ea. Cap. 1500#/24 Hrs. Cap. 390 Gal.	Bore Dia. - 4" Stroke - 5-3/4" Displ.-46,242 Cu.In. per Min. Submerged Type	Brunswick-Kroeschell Westinghse. Motor
2	Independent Refrig. Plants	B-K Jr. Model J-34	230 Volt D.C. 3/4 HP Motor		Brunswick-Kroeschell Westghse. Motor
8	Forced Draft Blowers	Horizontal Silent Vane Sing. Width Sing. Inlet Motor Driven	Cap.- 14,000 C.F.M. @ 3" H_2O BHP -11 @ 585/1075 RPM	Variable Speed 230 V. D.C. Motor Flexible Coupling	Sturtevant Fan Westghs. Motor
2	Feed Water Heaters	Vert. Coil Marine Type (2-Stg.Feed Htg)	Cap.In Series 220,000 #/Hr from 100° F. - 310° F. Stm. 1st Stg. 10# G. " 2nd Stg. 85# G.	W.P.-475#/Sq.In. Press. Drop 2 Htrs. 10#	Davis Co.
2	Lub.Oil Coolers	Single Pass(Water) Counter Flow	Cap.300 GPM L.O.from 130° F. to 100° F. 600 GPM Cool. Water @ 80° F.	Cool.Surf.900 Sq.Ft. Oil Press.Drop 10# Water Press.Drop 1#	Beth. Ship.
2	Evaporators	Vert. Coil #42-20	50 T/24 Hrs. of F.W. Stm. @ 75# Vapor Press. 10#	Heat Surf.ea.80 Sq.Ft.	Davis

			600 GPM Cool. Water @ 80° F.	Water Press.Drop 1#	
2	Evaporators	Vert. Coil #42-20	50 T/24 Hrs. of F.W. Stm. @ 75# Vapor Press. 10# 25 T./24 Hrs. of S.W. Stm. @ 75# Vapor Press. - 1#	Heat Surf.ea.80 Sq.Ft.	Davis
2	Distillers	Vert. Coil #18-7	Cap.-6000 Gal. Circ. Water - 80° F. Shell Press. - 1# G.		Davis
2	Filters	Paracoil Aerating Animal Bone Charcoal	Cap. 12,000 Gal. Dist. Water/24 Hrs.		Davis
4	Fuel Oil Heaters	Beth. Dahl #8 C Vert. Coil Type	Cap.-7500 #/Hr.-15° Baume Oil from 60° F.- 300° F. with Stm @ 360#	Htg.Surf. 60 Sq.Ft. Max.Oil Press.250#	Beth-Dahl
1	Fresh Water Heater		Cap.-15 Tons/Hr.from 50° F. to 140° F. with Stm. @ 150#		Alco Prod. Co.
1	Air Separator	"Hickman #70" 6" Outlet 6" Inlet	Cap.-220,000#/Hr.Feed Water @ 300° F. W.P. - 475# Norm. W.P. - 450#		F.M.Malany Co.
2	Main Air Ejectors	"C4" Twin,2-stage with Inter & After Condenser	Cap.-40# Free Air Vap.Press.-1.25 Hg(Abs) Vap. Temp. - 77° F. Circ.W.-162 GPM @ 85° F. Stm.Consump.655#/Hr.Ea. 2 Stg. Unit Stm.Press.- 150# Stm. Temp.- 450° F.	Int. & Aft. Cond. Cool. Surf.- Press.Drop-4 Ft.	Westghse. (Cond. Circ.)
2	Aux. Air Ejectors	"C2",Twin,2-Stage with Inter & After Condenser. 4-Pass	Cap. - 15# Free Air Vap.Press.1.5" Hg(Abs) Vap. Temp. - 77° F. Circ.W.-29 GPM @ 85° F. Stm.Consump.252#/Hr. Stm.Press. - 150# Stm. Temp.- 450° F.	Int. & Aft. Cond. Press. Drop 2.3 Ft.	Westghse. (Cond. Circ.)

No.	Unit	Type	Rating	Particulars	Vendor
2	Air Compressors.	Vert. Duplex 7" x 6" Sing.Act., 2-Cyl. Force Feed Lub. Intake Dia. 4" Disch. Dia. 3"	Cap.Free Air-100 Cu.Ft. 100# Disch.Press. & 575 RPM HP Motor -25 @ 575 RPM	Bore -2" Stroke -6" Constant Speed	Worth.-Comp. (Automatic Press. Reg.set to Operate @ 90# to 110#) Westg. Motor.
2	Lub. Oil Purifiers	#6 Sharples	Cap. - 350 Gal.Oil/Hr 2 HP Motor		Sharples Co.
1	Gland Leak-Off Exhauster	Vert. Type #1 -Des. #3 Sing. Width Sing. Outlet	1 HP Motor @ 2560 RPM		Sturt.- Fan Westghse. Motor
	Soot Blowers	2 - 2" Dialoy 1 - 2" Calorized 3 - 2" Plain 6 - 2" Plain	G9 Valve in Hd. Units G9 " " " " G9 " " " " G9 " " " "	(Air Htrs.)	Diamond Spec. Corp.
2	Press.Regulators for 8x10x24 Fire Pump		Stm.Rate-1200#/Hr.to Maintain 100# (G) Operating Press. 250# " Temp. 450° F.		Swartwout Co.
2	Press.Regulators for 5½x3½x12" Vs. Fuel Oil Pump		Stm.Rate-300#/Hr. to Maintain 250#/G Oper.Press.-250# " Temp. - 450° F.		Swartwout Co.
2	Press.Regulators for Port Feed Pumps.		Stm.Rate - 1800#/Hr. to Maintain 450#(G) Oper. Press.- 385# " Temp. - 675° F.		Swartwout Co.
1	Rev.Counter & Tell-tale	Averaging 2-Shaft	Brass Case		Cummings
2	CO_2 Indicators	Ramarex Co.Indicators	230 Volt D.C.		Permutit Co.
1	CO_2 Fire Ext.Syst.	Lux-Rich			W. Kidde Co.
1	Telemotor	Telemotor for Hydro-steerer			McLeod & Sons
1	Steering Gear	Hydro.Elect.4-Cyl. Rapson Slide Type	Rudder Area- 285 Sq. Ft.	2 - 75 HP Motor- 400 RPM. Westghse. (Constant Speed)	Amer. Eng. Co.
2	Liquidometers	Brass Cases - Silver Plated Dials			Liquidometer Corp.
	Machine Shop Tools	1 - 28" Barnes-Drill Press..... 1 16" Ohio Std. Shaper ..... 1 - #10 U.S.Emery Grinder ..... 1 - 18"x36" Rahn-Larmon Cap Lathe...	5 HP @ 1800 RPM 5 HP @ 1800 RPM 2 HP @ 1800 RPM 3 HP @ 1200 RPM	Pedestal 12"x1½" 20" Swing	J.T.Ryerson Co.

		1 16" Ohio Std. Shaper ..... 1 - #10 U.S.Emery Grinder ..... 1 - 18"x36" Rahn-Larmon Cap Lathe... 1 - 16" Canedy-Otto Upright Drill..... 1 - Racine Hacksaw -4" 2 - Sydney Eng.Lathes	5 HP @ 1800 RPM 2 HP @ 1800 RPM 3 HP @ 1200 RPM 1 HP @ 1750 RPM 1/4 HP @ 1750 RPM.	Pedestal 12"x1¼" 20" Swing 6" Stroke 12½"Swing-12"x8'	
8	Cargo Winches	Sing.Geared High Speed, 20" Drum	1800# @ 600 Ft./Min. 35 HP @ 300 RPM	Gypsy Hd.-13"Dbl. Helical Tooth Gearing	Cunningham
2	Cargo Winches	Dbl.Red.Heavy Duty 16" Drum -13" Hd.	1800# @ 600 Ft./Min. 35 HP at 300 RPM		Cunningham
4	Capstans	Self-Contained with heavy whelps without holes for hand bars	Cap.20,000# @ 50 Ft/Min. and to pull 5000# @ increased speed for taking in slack 75 HP Motor @ 600 RPM		Amer. Eng. Co. Westghse. Motor
1	Emergency Gen. Circ.Water Pump	Jennings self-priming horizontal centrif. single stage Disch.- 1½" Suct.- 1½"	Cap. 15 GPM @ 72' Hd Suction lift 12' 1 H.P. motor @ 3500 RPM	Connected to 30 KW Emerg.Generator	Nash - Pump Westinghse.Motor
2	"Short" Alarm Service Tank		Fuel Oil Separating in F.O. heating drains	High oil level alarm electric bell	C.V. Lane
2	Torsion Meters				Cummings
1	Air Conditioner	Direct expansion connected to refrig. plant compressors	For Main Cabin Dining Saloon		Brunswick Kroeschell
2	Fuel Oil Meters	Rotating disc. type		One each fire room	Buffalo

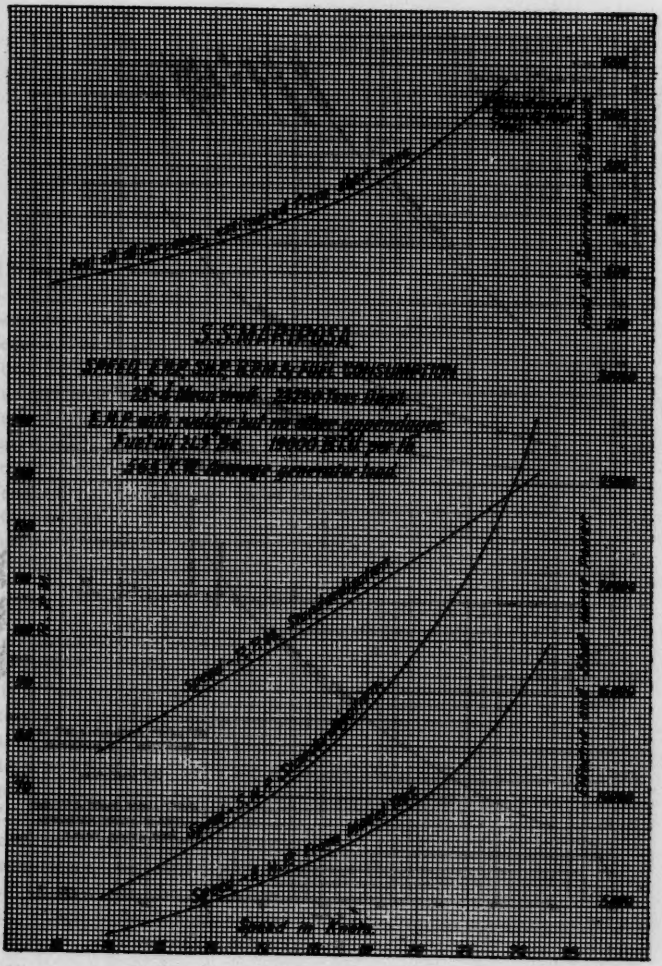


FIG. 6.

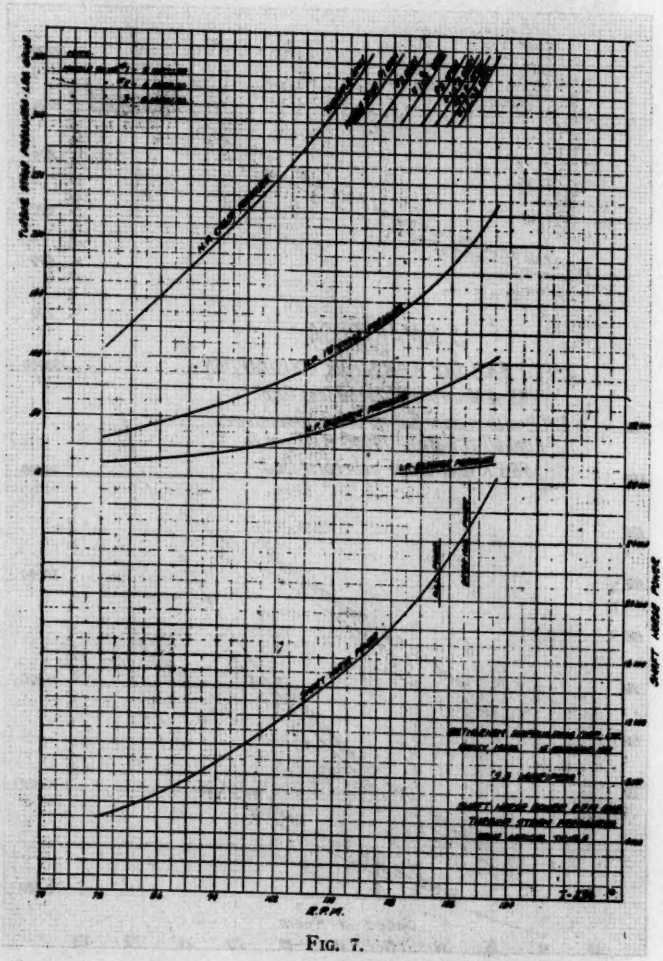


FIG. 7.

STANDARDIZATION.

Speed.	*R.P.M.*	*S.H.P.*
13.82	78.6	5,090
17.14	98.0	10,180
19.68	114.2	16,230
21.30	125.0	22,300
21.93	130.2	26,460
22.27	132.1	28,130

12-HOUR FULL POWER.

R.P.M.	124.7
S.H.P.	22,113
Generator Kw.	556
Generator H.P.	744
Total horsepower	22,857
Fuel per hour, corrected to 19,000 B.T.U., pounds	13,984
Fuel per total H.P. per hour, pound	.612
Last 5 hours of trial averaged	.607
Steam pressure at boilers, pounds square inch G	391
Temperature at superheater outlet, degrees F	671
CO_2 per cent	13.6
Fuel oil at burners, pounds per square inch G	140
Temperature degrees F	161
Degrees Baumé at 60 degrees F	21.9
B.T.U. per pound	19,132.0
Uptake temperature, degrees F	308
Air pressure in fireroom, inches water	.99
Air at burners, degrees F	280
Steam at H.P. chest, pounds per square inch G	361.5
Steam at H.P. first stage, pounds per square inch G	171.0
Steam at I.P. chest, pounds per square inch G	49.15
Steam at L.P. chest, vacuum, inches HG	13.2
Main condenser, vacuum, inches HG	29.45
Temperature, main injection, degrees F	44
Temperature, overboard discharge, degrees F	49
L.P. heater, feedwater in, degrees F	110.0
L.P. heater, feedwater out, degrees F	227.0
H.P. heater, feedwater out, degrees F	314.0

Figures 6 and 7 give the various data obtained on Standardization and Economy Trials.

My thanks are due to the Bethlehem Shipbuilding Corporation, Ltd., for their courtesy in furnishing me with data, plans, photographs, etc.

NOTES.

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THE FIRST MOTOR BATTLESHIP.

The British Motorship, December, 1931.

THE JUNKERS "JUMO 4" HEAVY OIL AIRCRAFT ENGINE.

Mechanical Engineering, November, 1931.

THE SURFACE HARDENING BY NITROGEN OF ALUMINIUM-CHROMIUM-MOLYBDENUM STEELS.

Engineering, October 9, 1931.

SOME ERRONEOUS IDEAS ABOUT OIL.

Mechanical World and Engineering Record, July 31, 1931.

PROTECTION OF METALS AGAINST CORROSION.

Mechanical World and Engineering Record, October 30, 1931.

THE PURDUE HIGH-PRESSURE BOILER.

Power, December 1, 1931.

THE FIRST MOTOR BATTLESHIP.

Full Description of the Machinery of the "Deutschland." Eight Engines, Totalling 56,800 B.H.P., Driving Two Propeller Shafts.

By W. Laudahn,* Berlin.

In technical circles it is already well known that the new German battleship *Deutschland,* which until it was launched was called the *Ersatz Preussen,* is driven by Diesel machinery. This is the first time that a large warship has not been fitted with steam plant, and it is, therefore, natural that the decision of the German Naval authorities should have aroused universal interest.

Clearly, the requirements were not easy to fulfil. In view of the limitations of displacement rendered necessary under the Versailles Treaty, by which the figure of 10,000 tons may not be exceeded, the permissible weight of the machinery plant was not more than that of a modern turbine installation, for any excess over this would have a detrimental influence upon armament and armor.

For the manufacture of the Diesel motors for the battleship the Maschinenfabrik Augsburg Nürnberg, A.G., were consulted. For more than 30 years this firm has been engaged in the development of Diesel machinery and has brought its productions to a very advanced state. So long ago as 1909, the M.A.N. decided to embark on the construction of double-acting two-stroke motors, and by the end of 1930 machinery of this class totalling over half a million horsepower had been installed.

It was obvious that even though the construction of the high-powered machinery needed for this battleship could only be undertaken by builders with prolonged experience, there would, nevertheless, be several new problems which that experience had not been able or had not been required to elucidate. A large number of investigations and trials of all sorts were needed, special studies of materials and methods of manufacture were made, and there had to be an abandonment of old ideas which could not be applied to the purpose now under consideration. It happened, fortunately, that there first came into question the machinery installation of the cruiser *Leipzig,* which involved the construction of a similar engine but of very much smaller power. Thus, a study could be made regarding the machinery, and many difficulties were thereby lessened.

The weight limitations of the machinery exercised an important influence upon the choice of revolution speed. The manner in which this influence is exerted and the methods of solving the problems in the construction of the machinery for the battleship are dealt with in the following description.

EIGHT COMPRESSORLESS 7100 B.H.P. ENGINES.

As the main propelling machinery, there are installed in the *Deutchland* eight compressorless double-acting two-stroke M.A.N. Diesel engines, of which each set of four drives a single propeller shaft through Vulcan gear. A general view of one of the engines is given in Figure 1. The nine working cylinders have a diameter of 420 millimeters and a piston stroke of 580 millimeters. When running at 450 R.P.M. each develops 7100 B.H.P., so that the total power at the couplings is 56,800 B.H.P. Allowing for the loss in the Vulcan drive and in the shafting, bearings, etc., it is estimated that there is a power of 54,000 B.H.P. available.

* Mr. Laudahn was responsible for carrying out the tests of the machinery of the *Deutschland.*—Editor.

The Vulcan gear reduces the speed of the shafts to 250 R.P.M., which is the maximum propeller speed for normal service. The weight of the engines is 8 kilograms or about 17.6 pounds per B.H.P., excluding the Vulcan drive, the propeller shafting, propeller, and air reservoirs.

The weight includes the proportionate weight of the necessary auxiliary engine and scavenging blower, also the oil and water pumps, but not the lubricating oil and cooling water in the engine when it is running, nor the air starting reservoirs.

The total weight of the whole plant, including propeller shafting, propellers, piping, gratings, floor plates and all auxiliaries amounts to 22 kilograms per B.H.P., or 48.5 pounds per B.H.P.

FRAMEWORK CONSTRUCTION.

That the weight has been brought down to such a relatively low figure is largely due to the employment in the construction of plate framing, electrically welded, and this is the first time that it has been adopted in engines of such high power. A long series of tests was carried out in which vibration was artificially caused, and the resistance and reliability of this construction was definitely proved. The framework, which, as in all large M.A.N. double-acting two-stroke engines, embodies through-bolt construction, begins at the floor level as a box-formed casting and ends at about the height of the middle of the lower cylinder in frame form, which allows easy accessibility.

The necessary cross-stiffening is obtained in the lower portion through the box casting, and above, at a height where the piston rod passes through, by means of corresponding distance pieces, while at the top the requisite stiffness is gained by bolting together the center portion of the cylinders. These are attached to the frame by means of through bolts, which serve for holding down the main bearings. This new arrangement of bearing renders it possible to dispense with a bedplate.

The crankcase is closed in below by plating, serving to receive the lubricating oil. The crosshead guides are welded to the framework and are bolted to provide further stiffening. From the side elevation (Figure 2) it will be seen that the controls are on the same side as the symmetrically arranged fuel pumps for the upper and lower sides of the cylinders. On the other side of the engine are the large scavenge air pipes and the upper and lower adjoining exhaust pipes. It is an advantage of the M.A.N. system of scavenging that it allows of the location of the large scavenging and exhaust pipe on one side of the engine.

ROTARY EXHAUST VALVES.

It is unnecessary to describe this method of scavenging, since it is well known to readers of this journal, but the arrangement for these particular engines is shown in Figure 3. It has already been demonstrated that it is suitable for high-speed engines, and it is scarcely an exaggeration to state that a similar system is almost a necessity in Diesel motors for battleships.

A newer development of this scavenging principle, which is clearly seen in Figure 3, is the provision of exhaust rotary valves, which close the exhaust gas piping from the cylinder at the moment when the piston begins to cover the scavenging ports in the cylinder liner. The object of this arrangement is to prevent air which enters through the scavenging ports from passing into the exhaust piping after the ports are closed. The result is that the compression within the cylinders on the compression stroke begins

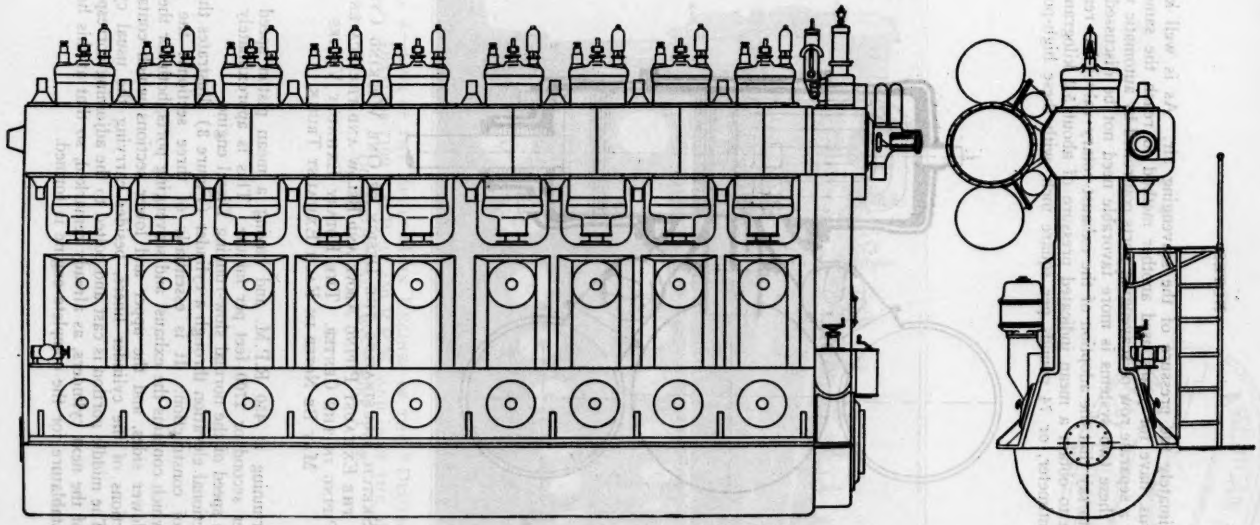

FIG. 2—FRONT AND SIDE ELEVATION OF ONE OF THE MAIN 7100 B.H.P. ENGINES OF THE "DEUTSCHLAND."

at approximately the pressure of the scavenging air. As is well known, Sulzer Bros. have for years used another method to reach the same end, employing a separate row of scavenging ports controlled by automatic valves. Which of these two systems is more favorable need not be discussed here. Suffice it to say that the adoption of the exhaust rotary valves has rendered it possible to obtain a mean indicated pressure of about 5.2 kilograms per square centimeter, or 74 pounds per square inch, with these high-powered

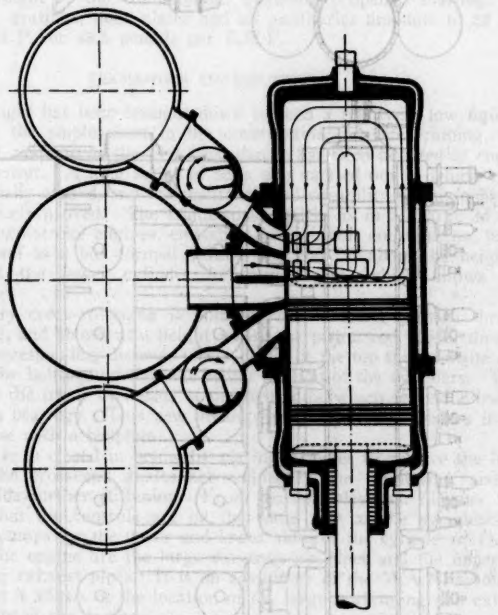

FIG. 3.—SKETCH ILLUSTRATING THE DESIGN OF ONE WORKING CYLINDER WITH THE EXHAUST PIPING ABOVE AND BELOW AND THE SCAVENGE PIPING IN THE CENTER. THE ROTARY EXHAUST VALVES MAY BE NOTED IN EACH EXHAUST TRUNK.

engines, running at 450 R.P.M. and having a mean piston speed of 8.7 meters per second or 1700 feet per minute. This is approximately double the piston speed of the normal slow-running Diesel engine.

The sectional elevation through a cylinder (Figure 3) illustrates the main features of construction. It is essentially of three sections: the middle portion, which contains the exhaust and scavenging ports, both for the upper and the lower sides, and the upper and lower sections which contain the other portions of the cylinder liners, besides carrying the usual cylinder covers. The middle portion is cast and bolted to the adjoining corresponding sections of the next cylinders, as already remarked, so that at this height a strong entablature for the complete engine is formed.

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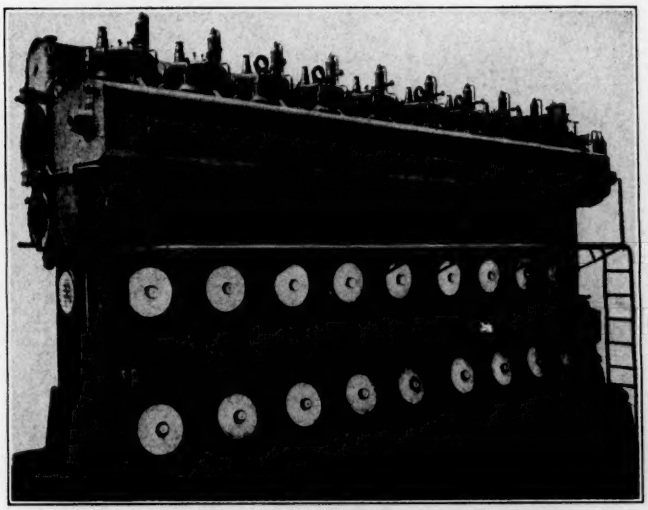


FIG. 1.—ONE OF THE EIGHT MAIN ENGINES OF THE "DEUTSCHLAND." IT DEVELOPS 7100 B.H.P. AT 450 R.P.M. AND IS OF THE M.A.N. DOUBLE-ACTING TWO-STROKE TYPE.

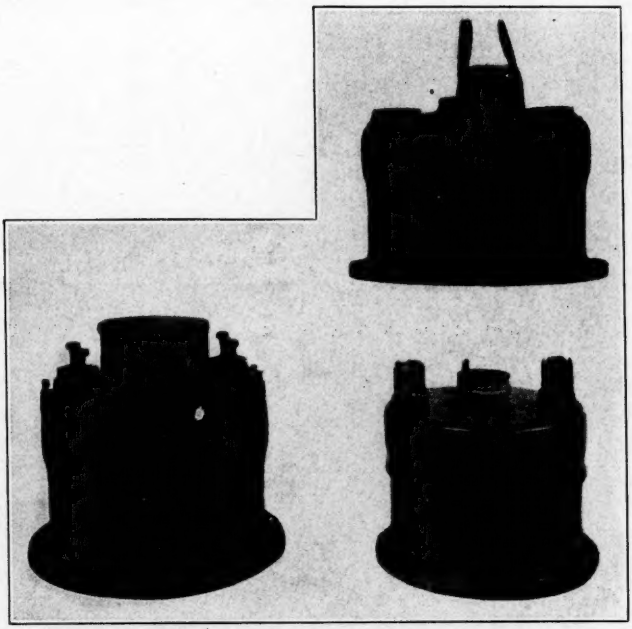


FIG. 4.—LOWER (LEFT) AND UPPER (RIGHT) CYLINDER COVERS OF THE ENGINE, THE COOLING MANTLE BEING SEEN LIFTED ABOVE THE COVER IN THE RIGHT-HAND ILLUSTRATION.

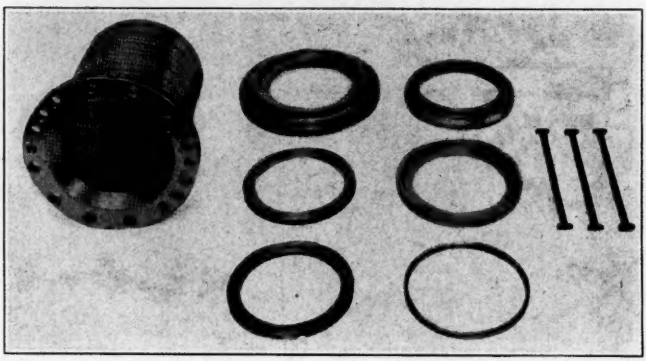


FIG. 5.—CYLINDER STUFFING BOX. ON THE LEFT IS THE COMPLETE STUFFING BOX AND ON THE RIGHT ARE VARIOUS PARTS.

FIG. 6.—PISTON, PISTON ROD AND CONNECTING ROD OF ONE OF THE MAIN ENGINES. THE COOLING OIL DELIVERY AND DISCHARGE PIPES FOR THE PISTON ARE SEEN.

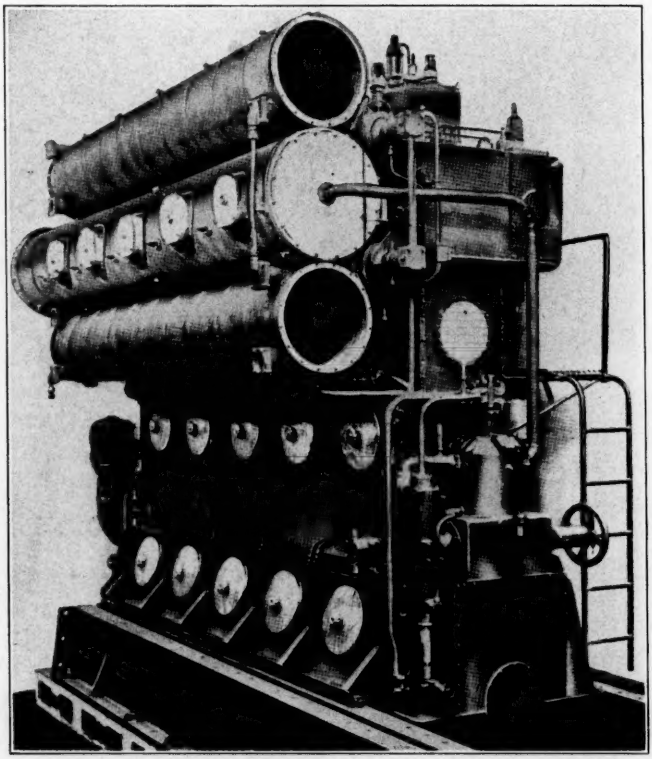


FIG. 7.—ONE OF THE FOUR AUXILIARY TWO-STROKE DOUBLE-ACTING DIESEL ENGINES INSTALLED TO DRIVE THE SCAVENGING BLOWERS.

The cylinder covers, which are of forged steel, are separate, and over them a cast steel mantle is placed. Figure 4 shows on the left the lower complete cylinder cover, while to the right is the upper cover, with the cylinder mantle above. This construction has several advantages. In the first place the erection is simple. Secondly, for the cylinder, which has to withstand high combustion pressures, specially chosen material may be used, in this way, by the employment of the simplest shape, obtaining the greatest strength against the pressure within the cylinder and the temperature stresses which arise. In the third place the necessary height for the removal of the pistons is relatively lower than in the usual system of construction, an advantage which is of very special value for warships, where height is of such vital importance.

VALVE ARRANGEMENTS.

For the upper portion of the cylinder there is a single fuel valve, while two are provided for the lower section. These valves are of the needle type with plain seats, and are oil-cooled. On the lower side of the cylinder the nozzles are naturally so directed that the piston rod is out of the range of the stream of injected oil. Nevertheless, a fairly considerable rise of temperature in the piston rod cannot be avoided, and to prevent this heating becoming excessive is an important and not too easy problem for the designer to solve. The rod is cooled by the oil which flows through a passage to the piston, and further by surface cooling in the stuffing box, which has its own separate cooling arrangement. In fact, there is a dual cooling system for the gland: in the outer portion it is cooled by water, and in the inner section by lubricating oil. Figure 5 shows the stuffing box and the individual parts.

In high-speed Diesel engines the piston rod and connecting rod are of special importance. Figure 6 shows these parts, including the piston, and the crosshead slipper. The piston body is in two parts, so that the upper and lower sections can expand freely under the influence of heat, but a joint is necessary in the interior of the piston because of the cooling medium. There are four grooves above and below the center for the reception of the piston rings, and the portion approximately in the center serves as a guide. The piston rod, which is bored to allow for the delivery and discharge of the cooling medium to the piston, is fixed to the crosshead so that its movement through bending stresses is prevented.

THE PISTON-COOLING SYSTEM.

Lubricating oil is employed for cooling the pistons. This was done in order to avoid the possibility of the mixing of any water leaking from the cooling system with the lubricating oil for the bearings. While it is easier to prevent leakage with water cooling when using telescopic pipes, in this case, with oil cooling, the delivery and discharge of the cooling medium have been effected through "walking pipes" which certainly are less easy to maintain free from leakage, but which have some manufacturing and constructive advantages over telescopic pipes. Slight leakage with oil cooling is unimportant.

In Figure 6 it may be seen that one fixed turning point lies on the crosshead guide, through which the oil from behind can pass, while the second fixed point is in the gudgeon pin. Through the link seen on the left the cooling oil passes into the gudgeon pin, which is hollow, and, on its return, through the bent pipe to the fixed swinging point on the other side of the

crosshead. From the swinging arm to the crosshead guide, the heated oil flows by the shortest path to the oil sump, from which it is pumped to the filters and coolers, together with the lubricating oil from the bearings. The delivery of the lubricating oil and the cooling oil to the engine is, however, effected by different circuits since different pressures are used.

A general view of a completed engine is seen in Figure 1. The gear is more clearly indicated in Figure 2. In the front view, to the right, the hand-wheel is seen, and in the side view to the left is the electric drive for the turning gear, which, in a certain measure, forms part of the engine construction. The slightly projecting casing encloses the drive to the camshaft, and the exhaust rotary valves. This shaft is not operated on the usual system with gearwheels and a vertical shaft driven from the crankshaft, but by means of two coupling rods set at 180 degrees; these drive a layshaft at the level of the camshaft. This layshaft turns the camshaft through spur gearing and operates the exhaust valve spindle by a chain. In the drive of the latter there is interposed a coupling operated under oil pressure, which, when the engine is reversed, allows for the regulation of opening and closing of the valves.

MANEUVERING GEAR.

The engine is maneuvered by means of a hydraulic-pneumatic servo motor. The only valves actuated from the camshaft are the starting valves, while the fuel pumps are timed and are driven also from the camshaft. The arrangement is simply carried out, and for the reversing mechanism no special device is needed for lifting the rollers off the camshaft. The cams have actually to lift only the fuel pump plungers and the pistons of the pneumatically operated starting air valves. For ahead and astern rotation, respectively, the two sets of cams are arranged side by side.

The longitudinal movement of the camshaft before reversing is effected by a mechanically operated and hydraulically damped gear, but the starting valve is actuated wholly pneumatically. Above the control shaft is situated a distribution cylinder for each starting valve, with a piston which, under the influence of compressed air, is forced into contact with its cam. The piston in the distribution cylinder is so shaped that the air for the actuation of the starting air valve is supplied according to the position of the engine crankshaft. In Figure 1 the starting air valves are clearly seen.

Compressed air for starting is supplied only to the upper side of the cylinders, while, simultaneously, oil is delivered to the valves in the lower cylinder, whereby there is a reduced cooling effect and better firing. Close to the fuel valves in the upper and lower cylinder ends is a safety valve in each case, also an indicator cock.

For each group of four main engines driving one propeller shaft is a common engine control station, from which, either together or separately, starting, reversing or stopping of the engines can be effected. At this position the whole of the control gear is concentrated, including a remote thermometer plant to enable the temperatures of the important points to be noted.

An important auxiliary for two-stroke engines is the plant for the supply of scavenging air. In view of the very large volume of air required, and the success of the present-day construction of turbo blowers, only this type of machine was considered. Each scavenging air blower is coupled to a Diesel engine, which differs from the main engine only in that it has five working cylinders instead of nine and is naturally not reversible. The number of cylinders of these auxiliary motors which, apart from the scav-

enging blowers, also drive a pumping unit for the supply of water and oil, was so chosen that one unit can supply the scavenging air for two main engines and for its own requirements. It was also decided that the specific cylinder power of the auxiliary engines should be lower than that of the main motors, and this was carried out partly by having a lower engine speed (425 R.P.M. against 450 R.P.M. of the propelling motors) and partly by a reduction of mean pressure. The cylinder power of the auxiliary engines works out at about 50 to 60 per cent of the corresponding figures for the main machinery, and by this means the reliability of the whole plant is augmented. The standardization of the measurements of the main and auxiliary engines is beneficial from the standpoint of operation and control, also in the reduction of spare parts which need to be carried on the ship.

AUXILIARY ENGINES.

Figure 7 gives an illustration of one of the auxiliary engines, of which four are installed. The similarity of construction to the main motors (Figure 1) is evident. While, however, in Figure 1 the camshaft is on the same side as the doors in the crankchamber, in the auxiliary engines, on account of their position in the ship, the arrangement is different and the crosshead guides are on the opposite side.

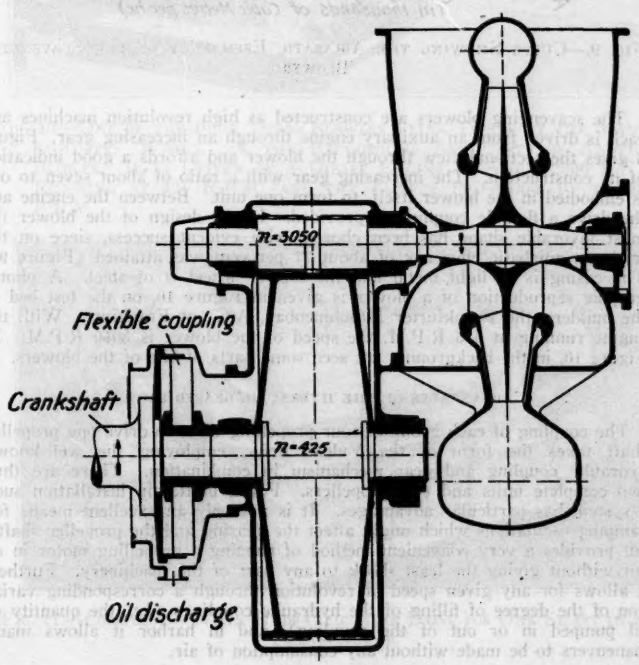


FIG. 8.—SECTIONAL ELEVATION OF ONE OF THE FOUR SCAVENGING BLOWERS.

At the back, to the left, is seen the turning motor and gear. At the forward end is a high-pressure compressor, driven from an extension of the crankshaft, for the supply of starting air. This unit can be taken out of operation by means of the handwheel which actuates a clutch; it is seen on the right. To the left of the compressor is the intermediate cooler, and in this illustration the position of the rotary exhaust valve is also seen. The vertical connecting pipe for the lubricating oil, which flows through the hollow shaft, is at the end of the engine to the right.

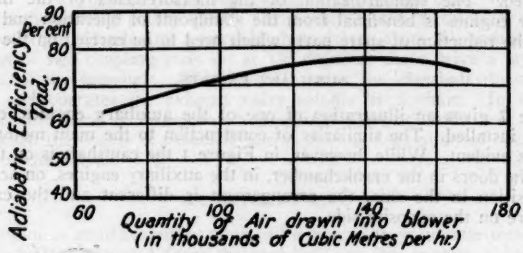


FIG. 9.—CURVE SHOWING THE ADIABATIC EFFICIENCY OF THE SCAVENGING BLOWER.

The scavenging blowers are constructed as high revolution machines and each is driven from an auxiliary engine through an increasing gear. Figure 8 gives the sectional view through the blower and affords a good indication of its construction. The increasing gear with a ratio of about seven to one is embodied in the blower itself, to form one unit. Between the engine and the drive a flexible coupling is provided. In the design of the blower the most favorable shape has been chosen, with evident success, since on the trials an adiabatic efficiency of about 77 per cent was attained (Figure 9). The casing is of light metal and the blower wheel is of steel. A photographic reproduction of a blower is given in Figure 10, on the test bed of the builders, the Frankfurter Maschinenbau, A.G., of Frankfurt. With the engine running at 425 R.P.M. the speed of the blower is 3050 R.P.M. In Figure 10, in the background, are seen some parts of one of the blowers.

ADVANTAGES OF THE HYDRAULIC GEARED DRIVE.

The coupling of each group of four propelling units to drive one propeller shaft takes the form of the Vulcan drive, employing the well-known hydraulic coupling and gear mechanism in combination. There are thus two complete units and two propellers. For a battleship installation such a system has particular advantages. It is not only an excellent means for damping oscillations which might affect the gearing and the propeller shafts, but provides a very convenient method of running a propelling motor in or out without giving the least shock to any part of the machinery. Further, it allows for any given speed of revolution through a corresponding variation of the degree of filling of the hydraulic couplings (*i.e.*, the quantity of oil pumped in or out of the coupling), and in harbor it allows many maneuvers to be made without any consumption of air.

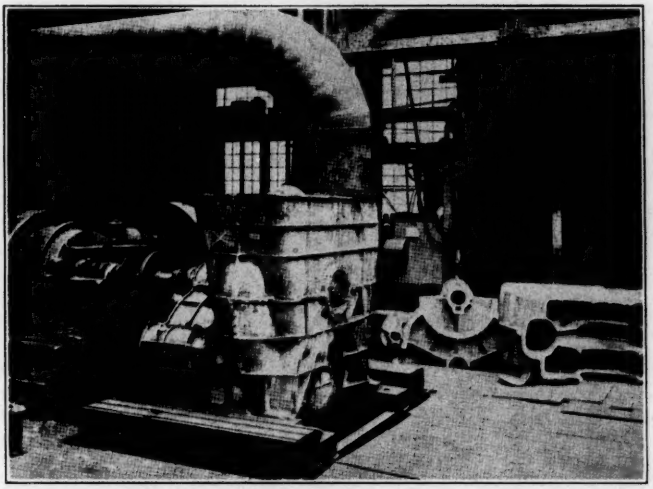


FIG. 10.—ONE OF THE FOUR TURBO BLOWERS BEING TESTED AT THE MANUFACTURERS' WORKS. IN THE BACKGROUND ARE PARTS OF ANOTHER BLOWER. IT IS DRIVEN BY A DIESEL ENGINE OF ABOUT 2300 B.H.P. RUNNING AT 425 R.P.M. AND THE BLOWER IS GEARED UP TO 3050 R.P.M.

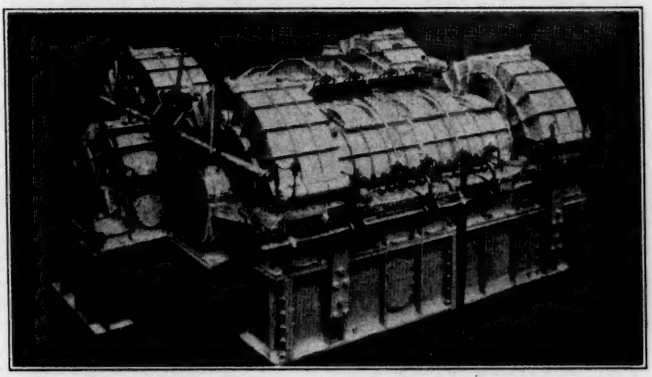


FIG. 11.—COMPLETE VULCAN HYDRAULIC GEAR DRIVE FOR ONE SHAFT IN THE "DEUTSCHLAND."

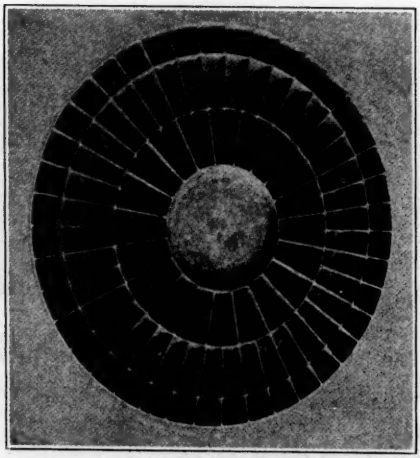


FIG. 12.—VANE WHEEL OF ONE OF THE HYDRAULIC COUPLINGS.

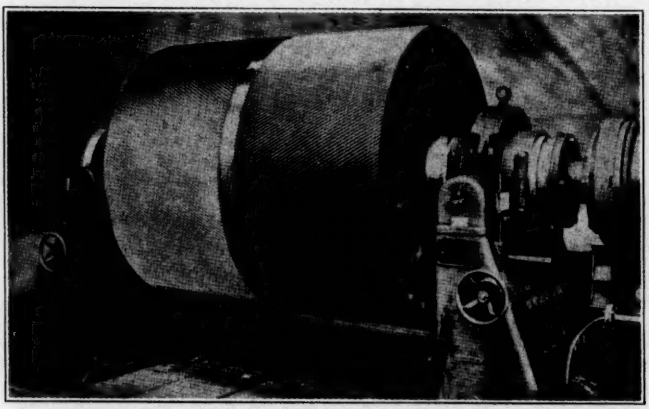


FIG. 13.—ONE OF THE MAIN GEARWHEELS DRIVEN BY PINIONS COUPLED TO FOUR DIESEL ENGINES, TWO ON EACH SIDE.

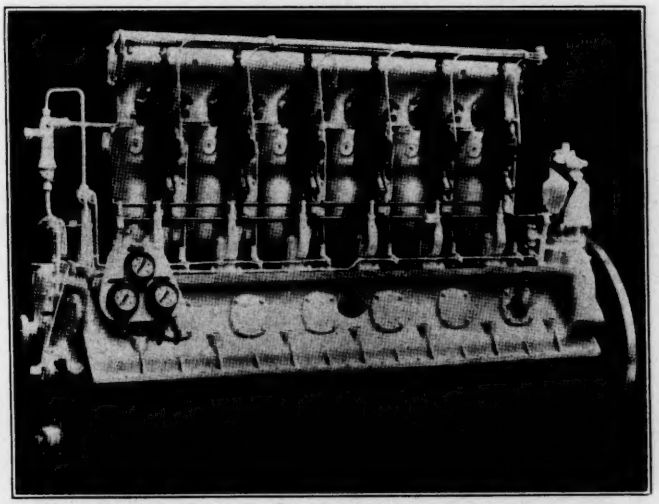


FIG. 14.—ONE OF THE EIGHT LINKE-HOFMANN-BUSCH 375-400 B.H.P. 1600 R.P.M. AIRLESS-INJECTION ENGINES INSTALLED IN THE "DEUTSCHLAND" FOR DYNAMO DRIVE.

This is carried out by keeping two of the engines of one group of four running ahead, and two astern; either pair can then be coupled to the shaft according to the direction of rotation required. It is true that with this arrangement only half the power is available, ahead or astern, but this is usually ample in harbor where high speed is not required. The time required for emptying and filling the couplings during maneuvering is only limited by the size of the pumps and the piping, which can conveniently be made sufficiently big for all practical purposes. Naturally, when the full power is required in one direction on a shaft it is not a difficult thing to reverse one pair of engines, as may be required, by compressed air, so that all four will then run in the right direction.

THE REDUCING GEARING.

Figure 11 shows the complete Vulcan gear for the *Deutschland*, the size of which can be gaged from the height of the man standing beside it. In the four small raised casings, one at each corner, are the oil-operated hydraulic couplings, to which the pinions are secured on each side. At the after end, over the large shaft to the left in the illustration, is the single-collar thrust block. The gearwheels are lubricated with oil supplied from nozzles, which appear in the illustration (Figure 11) as rows of small black pins. They are in communication with the line of lubricating oil piping. These oil nozzles are provided for the upper and lower side, also for ahead and astern rotation. At the end of the shaft, hidden in the illustration and to the right, is an electrically driven turning gear.

Figure 12 shows half of one of the hydraulic couplings. It consists of a shell, in which are inserted plates or ribs to give the requisite direction for the flow of the oil in the coupling. At the level of the shorter ribs, curved vanes are built in, and similarly formed vanes in the other half of the coupling provide the space in which the oil circulates. The halves of the couplings are attached to the ends of the shaft.

Above the joints is a regulator, the control lever for which is seen in Figure 11. The couplings can either be actuated separately or altogether. Figure 13 shows the large gearwheel which is driven by four pinions, two on each side. This hollow gearwheel is bolted to the corresponding coupling flange, and for the equalization of the axial thrust double helical teeth are employed.

The fact that the *Deutschland* is propelled by oil engines has involved the operation of the ship's auxiliaries by electricity. Hence a comparatively large generating plant is essential.

It consists of eight Diesel-driven dynamos each of 250 kilowatts. The dynamos were built by the A.E.G. and the Diesel engines by the Linke-Hofmann-Busch Werke, Breslau (Figure 14). Weight reduction was necessary with this installation and the speed of the engines is 1000 R.P.M., which is extremely high. They are six-cylinder single-acting four-stroke crosshead compressorless units, with fuel pumps and nozzles of the builders' design, which has given very satisfactory consumption results. The cylinder diameter is 220 millimeters, and the piston stroke 280 millimeters. At 1000 R.P.M. the power developed is 375 B.H.P. to 400 B.H.P., and the weight per B.H.P. without the dynamo is about the same as that of the main engines, *i.e.*, 8 kilograms, or approximately 17.6 pounds.

TRIAL RESULTS.

The delivery trials of all the propelling machinery have now been carried out at the works of the Maschinenfabrik Augsburg Nürnberg. The most interesting results, apart from the long duration and reliability trials, are

those of fuel consumption and mechanical efficiency. The fuel consumption values are shown in Figure 15 in relation to mean pressure, the measurement being the power generated at the engine coupling. The fuel consumption depends not only on the turning moment but also on the revolution speed. For the sake of clearness and the prevention of errors, the fuel consumption curves are given in relation to the turning moment and speed of revolution of the propeller drive. The consumption figures refer to fuel oil with a value of 10,000 calories per kilogram.

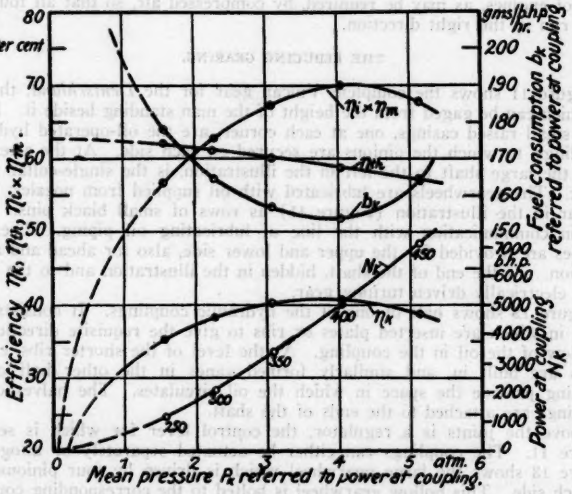


FIG. 15.—FUEL CONSUMPTION, POWER AND EFFICIENCY CURVES OF ONE OF THE 7100 B.H.P. DIESEL ENGINES OF THE "DEUTSCHLAND." THE FUEL CONSUMPTION IS LOWEST AT 400 R.P.M. AND 5000 B.H.P., BEING 153.5 GRAMS PER B.H.P. HOUR.

The minimum consumption figure as seen in the curves is attained with a mean pressure of about 4 kilograms per square centimeter, the corresponding engine speed being 400 R.P.M., and the actual consumption 153.5 grams per B.H.P.-hour, or less than 0.34 pound. This corresponds to the remarkable overall thermal efficiency of 41.2 per cent, which, however, at the maximum power, is reduced to 38.6 per cent.

For a complete estimate of the performance of the engine to be formed it is of interest to examine how closely the theoretical thermal efficiency (the ideal limit) is approached at a given speed. For this reason, in Figure 15 the theoretical thermal efficiency η_{th} is indicated. It is dependent upon the construction of the engine and the conditions under which it operates, being also influenced by the compression ratio, the excess of air, the maximum pressure of combustion, and the scavenging air pressure and temperature.

THERMAL EFFICIENCY.

This theoretical thermal efficiency is derived from a new book (not yet published) written by Dr. W. Pflaum, and entitled "IS diagramme für Verbrennungsgase und ihre Anwendung auf die Verbrennungsmaschine."* This work also takes account of the influence in variation in specific heat and the disassociation of gases, and deals with a comparison between the cycles of different types of internal-combustion engines.

It will be noted from Figure 15 that the theoretical thermal efficiency increases with a diminishing load. This is explained by the facts that the excess of air reduces the specific heat, and the temperature of combustion is lower. Over the whole range of power the thermal efficiency falls from 63 per cent to 57 per cent. This means that this is the highest percentage of the energy of the fuel which can be converted to actual work in an engine running without any losses.

SEPARATION OF LOSSES.

The difference between the theoretical thermal efficiency (η_{th}) and the actual overall efficiency (η_k) is due to thermal, mechanical and kinetic losses. The mechanical losses can be separated from the others, if the engine can be indicated when running light, or if the friction losses can be ascertained (for instance, when the engine, in running condition so far as temperature is concerned, is driven by an electric motor). Unfortunately, this was not possible during the acceptance trials of the engines on the test bed at the M.A.N. works. But the thermo-mechanical efficiency ($\eta_i \times \eta_m$) which is a product of the indicated efficiency η_i (the ratio of the indicated to the theoretical work) and the mechanical efficiency η_m (the ratio between the power delivered at the coupling to the indicated power) is given in the graph, and this is a representative measurement or scale, when estimating the performance of the engine.

If this type of Diesel engine is to be systematically developed it is naturally necessary to separate the various losses so far as possible, since it is only by this means it can be ascertained whether further improvements can be made.

The thermo-mechanical efficiency of the engine reaches 70 per cent. This is a high value which must be considered extremely satisfactory. The results of the acceptance trials have provided proof which is gratifying to the builders and to the German Naval authorities, that the propelling machinery of the battleship *Deutschland*, in spite of its being of the two-stroke type, operating with a mean indicated pressure of 5.2 kilograms per square centimeter and running at the high speed of 450 R.P.M. is as economical as the best large stationary Diesel engines, although the latter have mean pressures and revolution speeds much lower, and are not restricted in weight or space.

OVERALL FUEL CONSUMPTION.

This consumption figure does not include the power required for driving the scavenging pump. The actual power needed for scavenging, for the installation, represents 13.7 per cent of the total main machinery power. This gives a total consumption of 176 grams per B.H.P.-hour including

* "Entropy diagrams for combustion gases and their influence upon internal-combustion engines."

scavenging, or 0.385 pound per B.H.P.-hour. The scavenging air pressure is 0.35 kilogram per square centimeter, or 5 pounds per square inch.

It may also be remarked that the Diesel dynamos running at 1000 R.P.M. gave very satisfactory consumption figures in their acceptance trials. From three-quarter full load up to 10 per cent overload, the figure was 180 grams per B.H.P.-hour, and at half load 196 grams per B.H.P.-hour, while at one-quarter load at 1000 R.P.M. the consumption was 224 grams per B.H.P.-hour. The combustion at all loads was excellent.—"The British Motorship," December, 1931.

THE JUNKERS "JUMO 4" HEAVY-OIL AIRCRAFT ENGINE.*

The Junkers "Jumo 4" aircraft engine is an opposed-piston, two-stroke-cycle engine operating on fuel oil and employing the Diesel combustion cycle.

Figure 1 shows the scavenging and fuel-injection processes in the combustion chamber, and how the former can best be effected by the motion of opposed pistons. The charge of cold air enters through openings of large cross-section, flows through the cylinder without change in direction, and expels all of the hot gases of combustion through the exhaust ports. This procedure insures a clean charge, even at high engine speeds. In accordance with the method developed by Junkers in 1914 and used in all types of Junkers engines for many years, the air as it enters is set whirling spirally by the tangentially arranged scavenging ports, and maintains that motion during compression. Plunger-type pumps force a finely atomized spray of fuel into the highly heated, whirling compressed air, and a thorough mixing of fuel and air results, and in consequence complete combustion. There are no valves opening into the combustion chamber, and the inlet and exhaust ports are some distance removed therefrom. The cylinder head, which in most engines is highly stressed, is also eliminated in the opposed-piston construction.

The "Jumo 4" combines the advantage of opposed-piston operation with a better than average utilization of cylinder volume (25 horsepower per liter = 0.41 horsepower per cubic inch, and even more) and a piston speed of 12 meters per second (2360 feet per minute), without the aid of supercharging. The value of the two-cycle system, even for high speeds, is thus substantiated.

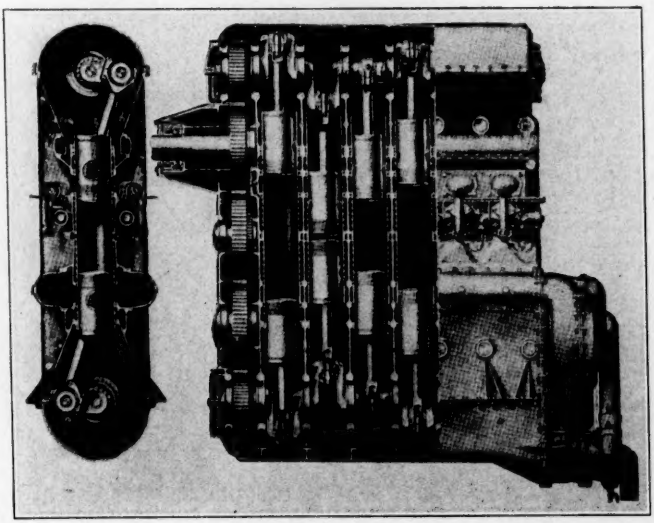
The scavenging air for the two-cycle system is delivered by means of a single-stage turbine blower of simple design.

CONSTRUCTIONAL FEATURES.

The construction of the housing is shown in the photograph reproduced at the beginning of the paper. The pistons transfer the gas pressures through connecting rods to the cranks at top and bottom which are geared to each other and to the propeller shaft. The wristpins are of comparatively large diameter and their lubrication is facilitated by pinholes in the connections between the wristpins and connecting rods, lubricant being thus introduced with the slightest movement in the bearings.

For high engine speeds, the two-cycle engine has a definite characteristic which protects the driving parts and insures smooth operation: the pres-

* From a paper contributed by the Junkers Research Institute, Germany, and presented by Fred. Melchoir, of the Junkers Corporation of America, New York, N. Y., at the Fifth National Meeting of the A.S.M.E. Aeronautic Division, Baltimore, Md., May 12 to 14, 1931.



INTERIOR OF THE "JUMO 4" HEAVY-OIL AIRCRAFT ENGINE.

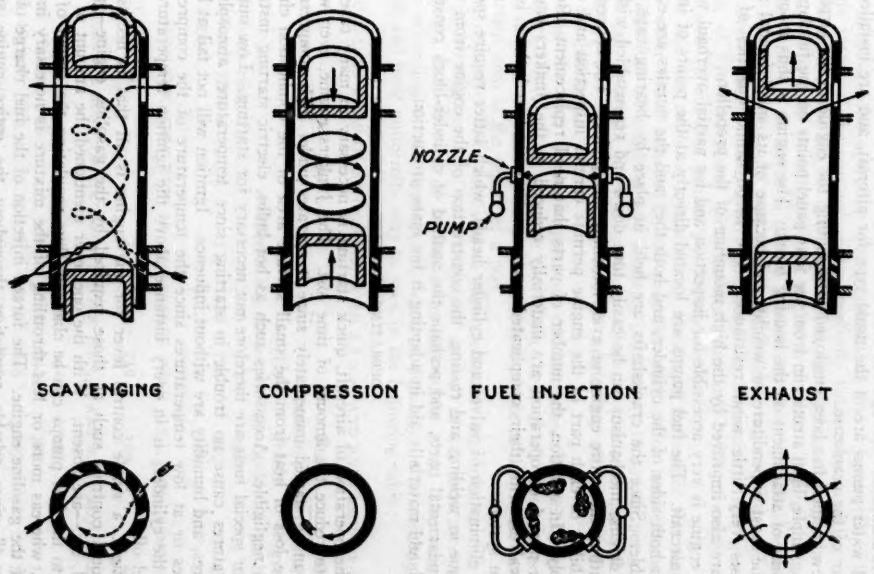


FIG. 1.—SCAVENGING AND FUEL INJECTION IN AN OPPOSED-PISTON ENGINE.

sures imposed on the main and connecting-rod bearings, the crankshafts, and the gearing are more uniform and are always in one direction.

Lubrication is obtained through oil supplied to the oiling points by oil lines in the crankcase. The bearings of the connecting rods get their oil from the crankshaft through holes in the ends of the latter. The lubricating-oil and water pumps are of the usual type for aircraft, and are installed at the rear of the crankcase.

A new method has been employed in mounting the engine in the airplane. In this, simple, light struts run from the four panel points on the fuselage to the points of attachment on the housing block. The engine is thus mounted with the least expenditure of weight, and because of its small frontal area it causes very little wind resistance. The aerodynamic qualities of the plane are also improved by the high mounting of the propeller.

The engine is very accessible for inspection and for partial overhaul while in the aircraft. The fuel pumps are located directly at the points of injection on both sides of the cylinder, and both they and the nozzles are easily accessible. Since the crankshafts are held in place by bearing caps, the entire driving mechanism can be easily torn down and reassembled without dismantling the entire engine or even loosening any piping. The convenient accessibility of each part of the engine permits careful inspection and easy assembly. In addition, the number of parts that need replacement after a certain period of operation are materially reduced in the Junkers engine, since valves, with their complicated parts, are not used and there is no ignition system.

The elimination of valves and cylinder heads, which latter require special technique in welding and casting, the construction of the engine from similar fundamental parts, and perhaps the method of cylinder-block construction, should materially aid in adapting it for mass production.

OPERATING FEATURES.

In the operation of aircraft, quick starting is necessary in many cases in order to reduce the amount of time lost. The Junkers engine, even when cold, can be started immediately since it operates under high compression, and the loss of heat from the small surface area of the combustion chambers is negligible. Accessories such as hot bulbs, electric starting installations, or special fuels are therefore not necessary for starting. Low outside temperatures cause no trouble in starting since temperature, atmospheric pressures, and humidity are without influence. Ignition will not fail at high altitudes or at low temperatures since the temperature of the compressed air in the cylinders is in every instance above the ignition temperature of the fuel oil.

In flight, a single control lever for the engine is all that is necessary. Additional controls such as those required by the gasoline engine—spark control, etc.—are absent. With the one lever mentioned the amount of fuel going to the fuel pumps can be changed, thus regulating the output of the engine, whereas more or less throttling of the mixture is necessary in the case of the gasoline engine. The forced injection of the fuel charge of the "Jumo 4" gives reliable regulation throughout the entire engine speed range, as well as smooth operation from low to high speeds. It is impossible for engine troubles to arise due to dilution of the lubricating oil by unburned fuel oil, and there is little probability that the exhaust manifolds will be clogged since the fuel is completely burned in the cylinder.

The same means used on the Junkers stationary Diesel engines for throttling the exhaust may be used for high-altitude performance. The

blower need only be changed for the more highly compressed air, since the single-stage turbine blower can still be built to give a good efficiency for a compression ratio of 1 to 1.8. If this ratio is not sufficient, a multi-stage blower can be built without great difficulty.

The six-cylinder in-line engine construction with opposed pistons favorably influences the operating characteristics of the "Jumo 4." The free inertia forces of the opposed pistons perfectly balance one another so that no vibration of the engine is transmitted to the fuselage through the engine mount. The quiet operation of the engine is further aided by the uniform torque, which is the same as that of a twelve-cylinder gasoline engine.

In February, 1931, the type test of the Junkers engine "Jumo 4," which had already been tested under light loads in September, 1930, gave it a rating of 720 horsepower (international standard) with a weight of 800 kilograms (about 2.45 pounds per horsepower).

The test was made on a special test stand and the output was measured by a water brake attached to the propeller shaft. For fuel, commercially available fuel oil weighing 0.86 kilogram per liter (7.18 pounds per gallon), which can be bought for 0.12 mark per kilogram (9.3 cents per gallon) in Germany, was used. Ordinary aircraft lubricating oil (Voltol F) was used for lubrication.

During the test, at the request of the Deutscher Versuchsanstalt für Luftfahrt (D.V.L.), an accurate record was kept of all parts subjected to wear, since an estimate of the probable length of life of the engine forms an important item in the report of a test.

The endurance tests consisted of three full-load runs totaling five hours with an average output of 724 horsepower, as well as five endurance tests of ten hours each—a total of 50 hours—at nine-tenths load. The runs were made according to the requirements without difficulty. The record of the results and their uniformity may be seen in the following table:

A—FULL-LOAD RUNS IN ACCORDANCE WITH C.I.N.A. AND D.V.L. REQUIREMENTS.

	Hours	R.p.m.	Hp. output	Fuel consumption, grams per hp-hr.	Oil consumption, grams per hp-hr.
1 Full-load run	1	1710	712	168	13
2 Full-load run	1	1716	725	169	14
Average		1713	719	168	14

B—SUPPLEMENTARY RUN IN ACCORDANCE WITH D.V.L. REQUIREMENTS.

3 Full-load run	3	1714	719	168	13

C—ENDURANCE RUNS IN ACCORDANCE WITH C.I.N.A. AND D.V.L. REQUIREMENTS.

First 10-hour run	10	1710	644	167	14
Second 10-hour run	10	1710	645	167	15
Third 10-hour run	10	1710	646	165	16
Fourth 10-hour run	10	1710	645	166	15
Fifth 10-hour run	10	1710	644	167	15
Average		1710	645	166	15

D—OVERLOAD RUN IN ACCORDANCE WITH D.V.L. REQUIREMENTS.

Overload run	1	1552	674	161	11

No fluctuations in the output and consumption of fuel and oil during the endurance tests, of ten hours duration each, were noticed, nor were any appreciable changes in the operation of the engine observed. The unusually low average fuel consumption of 166 grams per horsepower-hour is particularly worthy of note.

Figure 2 presents full-load and throttled-load graphs taken before and after the endurance tests which exhibit the characteristic qualities of a Diesel

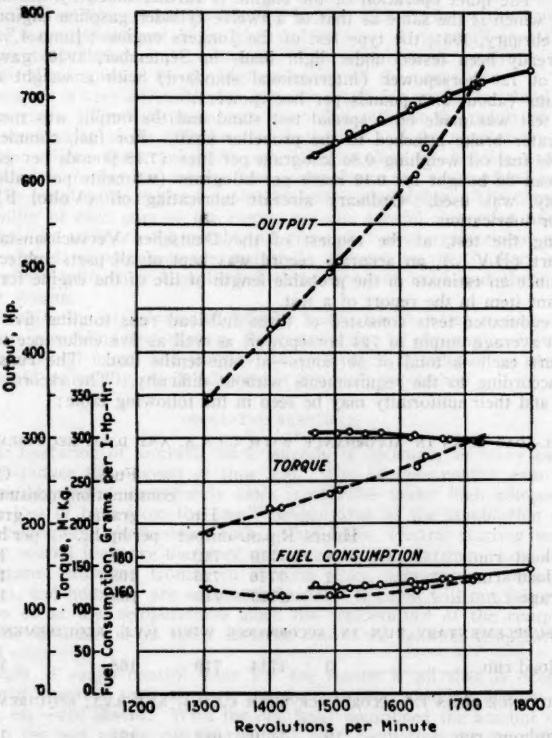


FIG. 2.—FULL-LOAD AND THROTTLED-LOAD CURVES.
(Solid lines, full load; broken lines, throttled.)

engine having practically perfect combustion. The substantially horizontal fuel-consumption curve at throttled load should be especially noted. In contrast to the gasoline engine, the fuel consumption does not increase with a decrease in load; in fact, it actually decreases and reaches the remarkably low value of 158 grams per horsepower-hour at two-thirds load. Inasmuch as airplanes actually fly at cruising speed with the engine partially throttled, this characteristic of the "Jumo 4" is of particular significance.

A one-hour overload test was also made, and in addition a one-hour test with the engine running at 1800 R.P.M. Particularly worth mentioning are the measurements of the quantity of heat in the oil and cooling water made at practically all operating speeds of the engine. In these tests less than 250 kilogram-calories (992 B.T.U.) per horsepower-hour were carried off by the water, while for the gasoline engine approximately 350 kilogram-calories (1389 B.T.U.) per horsepower-hour are carried off. This means that it is possible to cut down appreciably the radiator requirements and thereby save weight and room, as well as reduce wind resistance.

At the conclusion of the type test a study of the engine throughout its entire working range for vibrations showed that there were no critical crankshaft speeds. Further examination and measurement of all parts of the test engine, made at the request of the D.V.L., showed that no part was abnormally worn.—"Mechanical Engineering," November, 1931.

THE SURFACE HARDENING BY NITROGEN OF ALUMINIUM-CHROMIUM-MOLYBDENUM STEELS.*

By W. H. Cunningham, Assoc. Met., and J. S. Ashbury.

The purpose of this paper is to explain the process of nitriding as carried out productively by the firm with which the authors are connected, Messrs. Thomas Firth and John Brown, Limited, Sheffield. While the basic principles are similar, it will be understood that the exposure of test-pieces weighing something less than one pound to the action of ammonia gas at some elevated temperature in a small experimental furnace is vastly different from the treatment of a charge consisting of hundreds, and sometimes thousands, of parts, and weighing up to two tons. The essentials necessary for the surface hardening of articles with ammonia gas consist of a suitable furnace capable of accurate temperature control; a container made of some heat-resisting material such as nichrome, which resists the action of ammonia gas at nitriding temperatures, and which can be rendered gas-tight; a supply of anhydrous ammonia; and an apparatus whereby the percentage dissociation of the gas may be determined. It is also necessary to provide equipment for tinning, and some method by which the articles can be rendered perfectly clean and free from grease.

The Treatment of the Articles.—On receipt of the articles to be nitrided accurate representative measurements are taken for records purposes, after which any articles of which portions are required to be kept soft are suitably protected, as will be described later. The parts are washed in petrol to remove all adhering grease, boiled in several changes of water to remove all traces of petrol, and are then wiped with clean, dry dusters. The container, which should be clean, is packed with the articles to be nitrided in such a manner as to ensure a free circulation of the ammonia gas throughout the parts. One or two test-pieces, depending on the size of the charge, are placed amongst the articles so as to obtain a representative nitride case. These test-pieces take the form of heat-treated, polished nitralloy bars, 2 inches long by ½ inch square, sawn half through in the middle. When the packing is completed, the cover is placed on the container and bolted down securely, care being taken to ensure a perfectly gas-tight joint

* "The Surface Hardening by Nitrogen of Special Aluminium-Chromium-Molybdenum Steels on a Production Basis." Paper read before the Iron and Steel Institute, Swansea, on Thursday, October 1, 1931. Abridged.

The container is then drawn into the furnace, the current switched on, and the front sealed up with some heat-insulating material, after which the pyrometers are connected up. The nitriding period is taken from the time the box pyrometer registers 500 degrees C., and the temperature is kept between 495 degrees C. and 505 degrees C., throughout the run. The exhaust gas is tested every 4 hours to determine the percentage dissociation, and the supply is regulated in accordance with the results obtained. When the necessary period has elapsed the current is switched off, the front of the furnace removed, and the container drawn straight out and allowed to cool in the open. Throughout these operations, the ammonia-supply pipe is left in position, and the gas passed through the container at approximately the same speed as during the run until the whole has cooled to about 150 degrees C., when the gas is shut off. When cool enough to handle, the container is opened, the parts are removed and inspected, and those on which previous measurements had been made are again measured, and the results recorded.

The test-pieces are fractured to ascertain the depth of case, and surface hardness readings are taken by a suitable machine equipped with a diamond indenter. The parts are tested with specially hardened testing files, and hardness readings are taken on some of them to verify those made on the test-pieces. The parts are now ready for dispatch, and are packed carefully, so that they sustain no damage during transit.

Methods of Protection Against Hardening.—The authors have found by experience that the most efficient protection against nitriding is afforded by tinning the parts, where necessary, with a solder composed of 80 parts of lead to 20 parts of tin. The tinning operation is simplified by the use of a liquid flux, which, in their case, takes the form of zinc-killed hydrochloric acid containing some ammonium chloride. Wherever possible, the part to be kept soft is dipped into a bath of molten solder, which is maintained at a temperature around 400 degrees C., and the excess solder is brushed off by means of a stiff wire-brush. The solder is kept at this temperature so that, while it is hot enough to produce efficient tinning, there is no danger of affecting any previous heat treatment. In other cases, such as keyways and portions of an article which cannot be dipped without tinning surfaces that require hardening, the solder is applied with a soldering iron and blow-pipe, care being taken to remove any excess solder, as this would probably run on to other portions during nitriding. Keyways and threads are protected from nitriding as a matter of routine, unless otherwise desired.

In cases in which tinning either by immersion or by blow-pipe is impracticable on finished articles which require partial protection, the whole article is dipped in the molten solder at an intermediate machining stage; it is afterwards finally machined on the portions which require hardening, during which operation the tinned surface is removed, thus exposing metal suitable for nitriding. For efficient protection it is essential that the solder while in a molten condition should be actually worked into the surface of the steel; it is useless merely to plaster the surface with solder, as by so doing complete protection will not be afforded. In cases in which complete protection is unnecessary, parts may be kept relatively soft during nitriding by the application of a paint composed of a mixture of aluminium powder and commercial sodium silicate. Powdered chrome ore may be substituted for aluminium powder, and the paint should be of such a consistency that it is just possible to apply it with a brush. Internal threads present some difficulty in soldering or painting, but sufficient protection is afforded by packing tightly with asbestos wool and sealing the surface of the plugged hole with aluminium paint.

Growth of Parts.—A slight growth takes place during nitriding, which is only to be expected seeing that nitrogen has been added to the steel. This growth is very uniform, and appears to be a function of the time, the temperature, and the percentage of gas dissociation. The authors have found that on parts nitrided for a short period at a low temperature—namely, 20 hours at 485 degrees C.—practically no growth takes place, whereas on parts nitrided at 505 degrees C. for 100 hours the expansion varied from 0.001 inch to 0.006 inch, depending on the size and section. The growth is uniform on uniform sections, and the figure 0.0012 inch is very nearly constant for the growth which takes place on solid pieces from 1 inch to 12 inches in diameter. The growth which takes place on a round bar 1 inch in diameter is the same as that on a bar 6 inches in diameter, when they are nitrided together. The growth on a 1-inch diameter solid bar nitrided for 80 hours at from 500 degrees to 505 degrees C. varied from 0.0012 inch to 0.0014 inch. A bar of the same outside diameter but bored with a ½-inch diameter hole, would expand to the same extent on the outside diameter, but would be reduced to the extent of 0.001 inch on the inside diameter. A third bar bored with a ⅞-inch diameter hole, leaving only 1/16-inch walls, would expand approximately 0.005 inch on the outside diameter, and also expand on the internal diameter to the extent of 0.0012 inch.

This variation of internal growth appears to be controlled by the thickness of the surrounding metal—that is, the liability of the bore to expand increases as the thickness of the side walls diminishes. The above figures may vary slightly, depending on the previous heat treatment and stability of the material, but are given here as the average results obtained over a large number of tests. The "corner effect" which occurs on nitrided parts is the augmented growth which takes place on sharp corners. The growth on all surfaces combines at the corner, forming what might be termed a "fin," which is very brittle and liable to chip, as it consists entirely of nitride case, with no supporting core. The remedy for this is to provide corners of large radius wherever possible.

Distortion.—No distortion takes place during nitriding, provided that the piece is of uniform section, has no protected portions, and has been stabilized thoroughly to remove any machining strains. As has been previously mentioned, growth, which may be regarded as a form of distortion, differs with varying sections. For instance, a water-pump spindle with a long keyway on one side only will tend to bow during nitriding with the keyway at the top of the arc. This can be explained by the fact that a greater area adjacent to the keyway is exposed to the nitriding gases than on the opposite side, and, in consequence, greater growth takes place, with attendant distortion. If the keyway of such a spindle is tinned and then nitrided, it will bow slightly in the opposite direction, because no hardening, and therefore no growth, takes place on the protected portion.

This point will be made clear on referring to Figure 1, which shows three strips of nitralloy steel, 3 inches by ½ inch by 1/16 inch thick, tinned on one side only, and nitrided for periods of 30 hours, 50 hours and 80 hours, respectively. The upper strip, which was nitrided for 30 hours, had a deflection of 0.095 inch; the second, nitrided for 50 hours, a deflection of 0.113 inch; and the lower strip, nitrided for 80 hours, a deflection of 0.142 inch. These strips were quite straight before nitriding, and although this distortion would not have taken place had the pieces been of a much thicker section, the tendency to distort would still have been present, although not apparent because of the support afforded by the core. Thin bushes, which must be kept soft on the outside in order to obtain a grip on the hole into

which they are pressed, "bellmouth" to a small degree, but all this distortion is due to differential hardening, and would not occur if the pieces were nitrided all over. During the whole of their experience in nitriding, which covers over 300,000 parts, the authors have in no case found distortion of such a magnitude as to necessitate the removal of an undue amount of nitride case to effect rectification.

Hardness Testing.—For testing the hardness of a nitrided part, the authors use a Firth hardometer, capable of exerting a load of 10 kilograms or 30 kilograms. The latter load is suitable for testing nitride cases obtained by treatment for forty or more hours, but is too great for articles nitrided for less than 40 hours, for which the lighter load is used. From the surface of the nitrided specimen to be tested, 0.001 inch to 0.0015 inch should be removed by grinding on a felt buffing wheel dressed with flour emery and finally polishing on 00 emery cloth. This amount is sufficient to remove the softer outer layer, and expose the hard wear-resisting nitride layer, which will give a clearly defined impression of the diamond. Impressions taken directly on a specimen from which nothing has been removed will be found to have spalled so badly as to be unreadable. It is the authors' practice to obtain diamond hardness numbers varying from 1020 to 1170, and any tests which fall below 1020 are investigated, and, if necessary, the article is re-nitrided. The file test is useful for detecting non-nitriding steels which may have been included in the charge by error, and for testing the softness of protected portions.

Surface Defects.—The majority of surface defects occurring on nitrided articles can be traced to one cause—namely, decarburization due to mishandling in previous operations. Satisfactory nitriding will not take place on a decarburized surface, and it is found that, after nitriding such a surface, the decarburized portions have lifted and become friable, and will flake off on rubbing with the finger. This spalling effect sometimes occurs on articles having a uniform circular section, when it forms a strip of friable case from ¼ inch to ½ inch in width along its length. This is due to the removal of insufficient metal from this area owing to an error in centering during machining. In the case of articles having several diameters, spalling under these conditions would only occur on the greatest diameter. Parts which have merely been cleaned of rolling or forging scale will spall during nitriding and be quite unfit for service, and it is essential that from 1/32 inch to 1/16 inch of material should be removed from all surfaces which require hardening. On analysis, this spalled material was found to contain 0.04 per cent of carbon, whereas the steel from which it came gave on analysis 0.25 per cent of carbon, which shows that decarburization had taken place during some operation, resulting in spalling during nitriding.

Occasionally, unsatisfactory nitriding has been traced to the fact that the parts had been previously nitrided and then softened to allow of alteration owing to some machining error—or, in the case of die blocks, for re-cutting the impression—before re-nitriding. Tests were carried out to investigate the trouble, with the following results: Two pieces of nitralloy steel of known analysis were machined and nitrided, the diamond hardness number after nitriding being 1114. Piece No. 1 was then softened by heating to 790 degrees C., soaking for 2 hours, and slowly cooling in kieselguhr. The diamond hardness figure, after softening, was 551. A cut of 0.012 inch was machined off this piece, and the turnings analyzed; it was found that the carbon content had fallen from 0.27 to 0.16 per cent, while the other elements remained practically unaltered. The diamond hardness figure on the portion from which 0.012 inch on the radius had been removed was 320; a similar figure was obtained after a further 0.012 inch on the radius had been

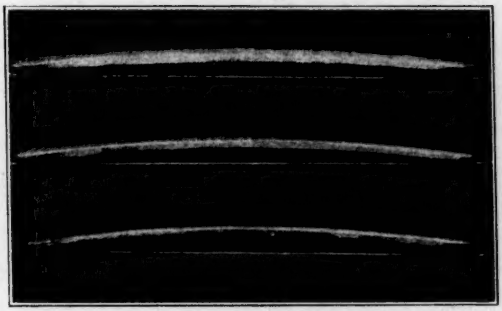


FIG. 1.—DISTORTION DUE TO UNEVEN GROWTH. THREE STRIPS OF NITRALLOY STEEL, TINNED ON THE UNDERSIDE AND NITRIDED.

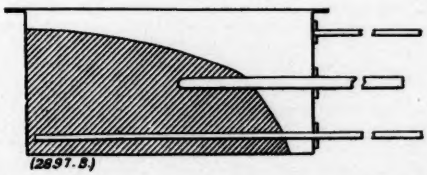


FIG. 2.—SECTION OF CONTAINER SHOWING METHOD OF PACKING.

removed, which showed that the core had been reached. The piece was re-nitrided for 80 hours, and then gave a hardness figure of 488, while the portion from which no metal had been removed after softening gave a similar figure. This shows that a second nitriding treatment cannot be carried out directly on an article which has been softened, and that a cut of 0.024 inch on the radius is insufficient to remove the effects of softenings. It was found that 0.035 inch must be removed on the radius before the piece would nitride satisfactorily.

Piece No. 2 was nitrided along with No. 1, and gave a similar diamond hardness number, namely, 1114. This was softened by immersion in a bath of molten chlorides at 790 degrees C. for 2 hours and cooling in air. The piece then gave a hardness figure of 460. The same procedure was adopted as with specimen No. 1; the carbon content had fallen from 0.27 per cent to 0.07 per cent, and the diamond hardness figure, after removing 0.012 inch on the radius, was 320. A further 0.012 inch on the radius was removed, when the hardness was again 320 (core hardness). After the second nitriding, the hardness of that portion from which 0.024 inch on the radius had been removed was 1066, and of that from which 0.012 inch was machined off was 774, while on the unmachined portion a figure of 551 was obtained.

It is obvious from these figures that, although nitrided parts can be softened by decomposition or diffusion of the nitrides so that alterations or additional machining can be performed, decarburization is an additional feature, and a second nitriding cannot be carried out successfully on articles which have been softened by either of these methods unless sufficient material is removed from the surface to get rid of the softening effects. This, of course, precludes the use of either of these softening processes on finished articles from which no metal may be removed. In cases in which it is found necessary to drill a hole or cut a keyway on an article which has been nitrided, the case may be removed by "pencil grinding," and machining carried out in the ordinary manner. Articles on which the final operation, prior to nitriding, has been oil-hardening and tempering, are often coated with a thin film of scale, and will not harden satisfactorily in this condition. A light sand-blasting will remove this scale and render the article quite fit for nitriding, providing that it is not a precision job.

A feature commonly met with is that known as "blueing." This effect occurs, to a greater or less extent, on almost every nitrided charge, and is usually confined to heavy masses of material or smaller pieces in close proximity to these masses. This blueing, which takes the form of vivid blue and pink tints, must not be confused with a dull slate-blue coloration which sometimes occurs and which should be avoided. Probable causes of the latter feature will be outlined later; neither should it be mistaken for temper colors, as this effect is in no way caused by overheating, but is merely an extremely thin film which can be easily removed by a few strokes of 00 emery cloth. This coloration is undesirable, inasmuch as it detracts from the appearance of nitrided parts; but apart from this the hardness and depth of case are the same as those obtained on an article nitrided in the same charge but which exhibits the characteristic grey color.

Heat Treatment.—Before nitriding can be successfully carried out it is necessary that the core be of sufficient strength to uphold the case, the core strength varying with the amount and nature of the work for which the article is required. The nitriding steels with which the authors deal are manufactured in six grades, the four most generally used having a carbon content ranging from 0.20 per cent to 0.55 per cent, other elements being the

same for all types. The carbon content, within these limits, has no effect on the hardness of the nitride case, and is governed solely by the mechanical properties required of the core. Examples of the mechanical characteristics of the steels after oil-hardening at 900 degrees C., and tempering at 600 degrees C. for grade 1, and 650 degrees C. for grades 3, 5 and 7, are given in Table I.

TABLE I.—MECHANICAL PROPERTIES OF NITRIDING STEELS IN TEST-PIECES MADE FROM 1⅛-INCH HAMMERED BAR.

Grade	Carbon Per Cent	Maximum Stress Tons per sq. in.	Elongation per cent	Yield Point Tons per sq. in.	Impact Value ft. lb.
1	0.46 to 0.55	90.4	11.0	83.6	19
3	0.36 to 0.45	77.4	13.5	69.7	38
5	0.26 to 0.35	56.8	18.5	44.0	57
7	0.20 to 0.26	48.8	22.5	32.8	73

It will be seen that this range covers the various requirements as to core strength met with in most types of service from steel with a high-tensile core strength necessary for die blocks, to a comparatively soft steel for use where the surface pressure is not high and intricate machining is involved. The mechanical properties imparted to the steels by oil-hardening and tempering are practically unaffected by the nitriding temperature, although the tensile strength is lowered to some small extent in virtue of the fact that the parts are held at 500 degrees C. over a long period of time. It may be mentioned at this point that the core strength of such articles as die blocks which have been re-cut and re-nitrided several times is lowered to such a degree that it is necessary to oil-harden and temper a second time in order to restore the tensile strength. Before an article is finish-machined, particularly if heavy machining operations have been carried out, it is essential that it should be stabilized by heating to 550 degrees C. for a period of time corresponding to the size of the article. This is done in order to remove any strains set up by machining, which, unless liberated before nitriding, would be released during the process, thus causing distortion of the article.

General Furnace Routine.—A nitriding furnace when once charged requires little attention, as the only variables are temperature and gas-flow. As the former is eliminated if the furnace is equipped with an efficient type of temperature control, it only remains for the attendant to regulate the feed of ammonia according to the results obtained from his dissociation tests. It is, however, necessary to exercise great care when packing the container with articles to be nitrided, as uneven hardening, and, in some cases, total failure to harden, may be the result of slipshod methods. That parts must be cleaned and free from grease before nitriding has already been mentioned. Many articles are received on which, in order to save costs, machining has only been done on those portions which require to be hard, the rest being left in the rough scaled condition. Die blocks, for instance, only require hardening on the face which carries the impression, and it is only necessary for that face to be free from scale. Precautions must be taken, however, before any large heavily-scaled areas are included in a nitriding charge, as the presence of such areas seriously upsets the ammonia dissociation, with consequent detrimental effects on the rest of the charge.

It is the authors' practice either to sand-blast those areas to free them from scale, or to paint over the scaled surface with the aluminium paint. The latter method is usually adopted, and is quite effective in preventing any deleterious effect which the large unprotected oxidized areas would occasion. When packing the container, care must be taken to place tinned articles in such a position that no excess solder will fall on to others below them and cause undesirable soft spots, as the melting point of the solder is considerably below 500 degrees C. Round shafts and spindles having tinned areas should be separated from each other by lengths of aluminium or nickel wire; if they are grouped together with the protected areas in contact with each other, the tin will be drawn along the shaft or spindle by capillary attraction, and thus cause a line of protection where it is not desired. All articles should be placed so that the gas can circulate freely around them, and this is facilitated by using nickel-wire grids with which to separate the various layers.

Articles, such as cylinder liners, bushes, or fuel-injector bodies, in which a hardened bore is of first importance, should be placed one or two inches clear of the bottom of the container and in a vertical position, so that the gas has an unrestricted flow through them. This method is particularly to be recommended when packing parts with bores of small diameter. The authors have found that when such parts are nitrided in a horizontal position, there is a danger that the upper portion of the bore will not nitride properly. Their investigations of the cause of this faulty nitriding indicated that a line of gas bubbles, probably hydrogen, was trapped and held on to the surface of the steel at the highest point in the bore, so preventing complete nitriding from taking place on that area. It has since been their practice to place all such articles in a vertical position and as near to the open end of the ammonia-inlet pipe as can be arranged, so that the gas may circulate actively through them.

To ensure even nitriding throughout a charge, the container should not be packed to more than two-thirds of its capacity. Figure 2 shows the method of packing the authors have found to give the most uniform hardness and depth of case. The portion shown hatched represents the space occupied by the articles to be nitrided, while the remainder of the container is left empty, as it has been found that articles placed near the front end of the container—the gas-outlet end—only become partially nitrided. A possible explanation for this failure to nitride is that the ammonia, on its way to the exit, after passing through and being dissociated by the articles, is in such an attenuated condition as to be incapable of further nitriding. The obvious solution for this trouble is to turn on more ammonia, but it has been found that on doing this the articles in the immediate vicinity of the ammonia inlet receive too much gas, and are, in fact, cooled to such an extent that they fall below the nitriding temperature.

The slate-blue coloration on nitrided articles, previously mentioned in the section dealing with surface defects, has been found to be due to: too high a nitriding temperature; air being allowed to enter the container while the articles are still at about 500 degrees C.; and leaks in the container, gasket or pipe flanges. This dull slate-blue coloration should be studiously avoided, as parts possessing it will usually be found to have a very brittle case, sometimes coupled with a low hardness value, the brittleness in some cases persisting for a depth of 0.006 inch. Apart from this, there is an increase in growth above that which occurs on correctly nitrided parts. Although there is a saving of time by nitriding at high temperatures, in the authors' opinion the results are not so good as those obtained by nitriding at 500 degrees to 510 degrees C. Many undesirable effects are produced by higher tempera-

ture treatment, such as greater growth, distortion due to sagging, liability to surface cracks, and the reduction of core strength and surface hardness. There is also an enormous increase in the dissociation of the ammonia, with a consequent increase in the amount of atomic hydrogen present, resulting in a greater tendency towards decarburization.

It is an unnecessary waste of time to allow the container to cool down in the furnace after the nitriding run is completed, as it can be quite safely drawn straight out and allowed to cool in the open, provided that no air is allowed to be drawn into the container through the inlet or exit gas pipes.

In the majority of cases where the slate-blue coloration has occurred, the trouble has been found to be caused by leaks in the container, either through the welded seams, the gasket or the pipe flanges. Faults in the welded seams can, of course, be effectively rectified by re-welding, although as a temporary expedient a stiff paste made by mixing kieselguhr with sodium silicate may be used to seal the leak.

The joint between the container and the pipe flanges may be rendered gas-tight by employing an asbestos washer smeared on each side with the aforementioned kieselguhr and sodium-silicate paste. It is found that the best results are obtained by working with a gas dissociation between 25 per cent and 30 per cent, and a pressure of 1 inch to 2 inches of water in the wash-bottle, the pressure depending on the amount and intricacy of the articles to be nitrided.—"Engineering," October 9, 1931.

SOME ERRONEOUS IDEAS ABOUT OIL.

By H. N. Bassett.

There was a time, happily now past, when oil was oil and nothing more, when buyers considered the price first and the lubrication last. With the growth of the great oil combines and the scientific study of lubrication, that time has gone forever, for much more is known and understood generally about the way oil functions. Many plants have their own chemists, who are expected to know something about the lubrication of the machinery in the plant, and who make recommendations more or less adequate and correct, according to their experience. There are still in circulation some quite wrong ideas about oil, however, which are very difficult to overcome. Some of them are purely matters of prejudice, while others have some basis in experience.

It is thought sometimes that a light oil weighs less than a heavy one, but these expressions have nothing to do with the weight of the oil, but refer to its viscosity. A light oil is one of low viscosity or very fluid, and a heavy oil is one which is less fluid. Specifications sometimes differentiate between oils by means of specific gravity, but this is really of little value today. Once oils were more nearly straight distillates, but nowadays they are usually blends of distillates, and the blending does away with the indication that the specific gravity used to furnish of the field of origin of the oil.

Emphasis is sometimes laid upon the color of an oil, and there is a definite preference on the part of many buyers for an oil either dark-red or golden-yellow in color. This preference changes from time to time, and one year the demand will be for a golden oil, and the next it will be for a redder one. The demand must be met, and frequently it gives much trouble in the refinery exactly to match the shade requested. There is a firm prejudice against black motor oils, for example, and in competition the dark oil has

little chance against the red or green. Sight is lost entirely of the fact that a light color can be obtained only by refining, and the very process which lightens the color results in the removal from the oil of some of its most valuable lubricating properties. Transformer oils are very highly refined to enable them to stand up to the exacting demands made upon them, but they are not specially valuable as lubricants. Refining to too high a degree, therefore, to obtain a good color may result in a lubricant definitely worse than the darker oil from which the better-colored oil was made.

Oil is often judged by its fluidity at the temperature of the air, regardless of the temperature at which it will be used. This is the case more especially with machinery oils, for cylinder oils generally receive rather more attention. Machinery bearings run normally at about 100 degrees to 140 degrees F., and it is at this temperature that the viscosity should be considered. Provided that the oil will pour easily at the air temperature, and is not too thick to lubricate efficiently before the bearing becomes hot, its actual viscosity at the air temperature is a matter of no importance. It may easily happen that if too much reliance is placed on the viscosity at the air temperature, an oil will be chosen which thins out too much in use, which is to be avoided most carefully.

There is a prejudice also against oils which are thin, and it is commonly thought that the thicker an oil is the better will it be as a lubricant; but this is not the case. Other things being equal, the thinner the oil is the better, for the friction in a well-oiled bearing is due purely and simply to that in the oil itself (fluid friction), and this increases with the viscosity of the oil. The lower the viscosity of the oil, therefore, the less the frictional losses in the bearing, and, provided that the oil is thick enough to form a film that will carry the load required, the more fluid it is at running temperature the better. Thin oils also lead to low running temperatures, and if a bearing is warmer than it should be, often the use of a thinner oil will make it run cooler, while the employment of a heavier oil will result in a rise in temperature.

It must be observed that viscosity itself has nothing at all to do with lubricating value, as it affects merely the fluid friction in the bearing. This will be obvious when it is considered that "golden syrup," made from sugarcane, may have the same viscosity as an oil, but would be quite useless as a substitute for it.

Attention is drawn sometimes to a carbon test in which oil is burnt off on a hot plate, and the residue, if any, examined. Little is to be learned from this test, for the oil does not exist which will not burn away completely (save for a small residue of oxide of iron from the still in which it was made) if heated for long enough and to a temperature sufficiently high. Various much more scientific tests have been worked out, and have been standardized, but none of them gives results which yet can be correlated directly with the deposit that is left in an internal-combustion engine.

More important than this carbon test is the gumming test. Mineral oils are supposed not to oxidize appreciably in use, but some of them certainly have a tendency to form gummy deposits, especially when used in hot situations. This is generally taken to be indicative of a lubricant of low quality, but it merely indicates that the oil has not been refined so far as some others. The formation of gum is due to the oxidation of unsaturated hydrocarbons in the oil, and it is to these hydrocarbons that the oil owes its value as a lubricant. It is precisely because in transformer oils all the unsaturated hydrocarbons have been removed that the oil is stable and is such a bad lubricant. Gumming may be due to the fact that the oil in question is a

compounded oil containing a proportion of fat or fatty oil. The addition of such to a mineral oil has the effect of improving it as a lubricant, though it may increase its tendency to gum when in use.

Sometimes a great deal of attention is given to the flash-point of the oil. This is a matter of no importance at all from the point of view of lubrication, but it is a protection against adulteration of the oil with low-volatility oils like solar oil and kerosene, which might be added to reduce the viscosity to a required figure. If the flash-point is specified it should not be placed too high, for the various ranges of distillates which furnish lubricating oils have their normal flash-points, and to match a viscosity of one range against the flash-point of the next higher range involves extra work for the makers, and inevitably raises the price of the oil without corresponding gain to the user.

Oils are sometimes thought to be such that they gradually wear out in use; but this is not so. Oils do not wear out in the usually accepted sense of the word, and when an oil is dirty it may be cleaned and used again. Provided that the cleaning is well done, the cleaned oil is just as good as the old. This does not apply to compounded oils, which are not so good after use as before, owing to the gradual increase in the acidity due to the fat or fatty oil originally present.—"Mechanical World and Engineering Record," July 31, 1931.

PROTECTION OF METALS AGAINST CORROSION.*

With Reference to Some Problems in Aeronautical Engineering.

By H. Sutton, M.Sc., A.F.R.Ae.S.

Recent research work has shown that in a comparatively short space of time the fatigue strength of most industrial metals and alloys under conditions of fluctuation or alternating stress is reduced substantially by contact with corroding agents such as saline waters, and in some cases the static tensile strength under conditions of prolonged application of stress appears to be reduced appreciably under the same conditions. These effects are observed before substantial reduction of section has been caused by the corrosive agency, and in many cases no serious damage is observable by visual examination of the specimens under test.

PROTECTION OF STEEL PARTS OF AIRCRAFT.

During the past ten years marked developments in the so-called "stainless" or "non-corroding" steels have taken place, and in this country application of these steels in aircraft construction has now assumed extensive proportions. Important advances made by steel manufacturers have usually been followed by application of suitable steels to the manufacture of aircraft. It is now recognized that the high degree of resistance of these steels to corrosion is due to the protective effect of the films which form under normal conditions of use upon the exposed surface, and to the rapidity with which such films form again at places where rupture of the original film occurs by reason of chemical attack or mechanical breakdown. The film-building properties are gained by the addition of special elements, notably chromium, to the steels, and the attainment of a high degree of corrosion resistance in this way may therefore be regarded as the result of the application of a method of protection. However, this paper is more particularly devoted to the protecting of less resistant metals used in aircraft.

* Abstract of paper presented to the Royal Aeronautical Society on the 15th inst.

CADMIUM PLATING.

Electro deposits of cadmium on steel parts have been found to be capable of affording a high degree of corrosion-resistance, particularly where mechanical abrasion or severe exposure to the influences of weather does not occur.

The deposition is usually effected in baths consisting of a solution of cadmium-sodium cyanide containing some free sodium cyanide. Under the conditions of use normally prevailing in most works it is found necessary to use some insoluble anodes, as well as cadmium anodes, in order to prevent the bath becoming too high in metal content and to avoid excessive consumption of cyanide. In order to obtain coatings of thickness within the desired range, careful control of the plating operation is essential, and of first importance in this respect is the matter of maintaining the bath in a suitable and steady condition as regards metal and free cyanide contents, since the cathode efficiency is influenced appreciably by the composition of the bath. Additions at regular intervals of the amount of cyanide indicated by tests of the bath solution to be required, permit uniformity of working properties and the desired consistency in thickness, quality, and adhesion of the deposits to be obtained.

The degree of adhesion of deposits of cadmium and other metals can usually be observed by simple bend tests on samples of small section in suitably ductile materials—*e.g.*, mild-steel sheet, streamline wire, or tie-rod.

Several cases of unsatisfactory performance of cadmium-plated wires have been caused by imperfect cleaning of the wires before plating; too thin deposits, due possibly to bad contacts during plating; splashing of plated wires with solution or washing-water during standing in the plating shop, and to unsatisfactory adhesion of the deposits. The careful preparation of the surface of the wires permits the detection of defects which might otherwise escape observation, and the white color of the cadmium coating causes any unusual feature to be observed very readily.

In operating plating plant it is usually found that small articles receive a thicker deposit than larger articles plated at the same time and under the same conditions, and that articles placed near the top of the bath receive a thinner deposit than those situated nearer the bottom of the bath. These observations are readily explained by consideration of the conditions prevailing within the plating bath. On prominences on the cathode the current density is higher than that on large plane surfaces, and the amount of metal deposited on such prominences will therefore tend to be greater. For this reason, test-pieces plated for the purpose of checking the thickness of deposit should not be too small in relation to the pieces they are intended to represent. The deposition of metal from the bath solution at the cathode results in a substantial decrease in density of the solution about the cathode, and in a current of electrolyte having a low density continually passing upwards over the cathode surface during operation of the bath. Articles placed near the bottom of the bath are continuously fed by electrolyte of normal density, while those near the top are surrounded by electrolyte of depleted metal content, and therefore receive a relatively thinner deposit. The conditions here mentioned prevail only in baths which are not agitated, but agitation of the plating baths is attended by difficulties owing to any sediment present being circulated with the electrolyte.

Cadmium plating of steel is usually attended by some degree of embrittlement, except in the case of very soft and ductile steels. The degree of embrittlement has usually been found to be considerably lower than that experienced after zinc plating in cyanide baths. Low-temperature heat

treatment—*i.e.*, heating to 100 degrees C. to 150 degrees C.—after plating, usually results in practically complete recovery of ductility unless the plating operation has been unduly prolonged and the deposit considerably thicker than the 0.0003 inch to 0.0005 inch deposit normally employed in aircraft practice.

According to McAdam (Am. Soc. Mech. Engnrs., December, 1928), cadmium electro deposits are of considerable value in raising substantially the corrosion-fatigue limit of spring steel in contact with fresh water. In his experiments, samples having a deposit 0.0004 inch thick gave a higher corrosion-fatigue limit than samples having 0.0002 inch.

ZINC PLATING.

Zinc electro deposits are usually harder than those of cadmium, and are probably slightly more durable under normal conditions of use. While excellent deposits of zinc can be obtained from the sulphate or chloride type of bath, deposition on steel parts is usually effected in zinc-sodium cyanide baths, owing to the better "throwing power" obtained with the latter.

HEATING PROCESSES.

Several processes are employed for the production of zinc coatings by the hot-diffusion or "Sherardizing" method. This method serves a useful purpose in the protection of steel tubes and fittings of such shape as to prevent adequate deposition of metal by electrolytic methods on recessed parts or internal surfaces. The treatment generally consists in heating the parts for several hours in sealed containers filled with a mixture composed essentially of zinc oxide and metallic zinc in finely divided form. A coating of metallic zinc is deposited on all parts of the steel fitting undergoing treatment, and actual diffusion of the zinc into the steel occurs. The protection afforded by this means is usually not quite so good as that afforded by electrodeposited zinc coatings of good quality, and considerable variation in thickness of the coating may occur unless precautions are taken to prevent this.

The effect of the modern forms of treatment of the Sherardizing type on the mechanical properties of aircraft steels is not very marked. In the case of a cold-rolled medium-carbon steel of 45 to 50 tons per square inch proof stress (0.1 per cent) and 60 to 62 tons per square inch ultimate stress, treatment of the Sherardizing type raised the limit of proportionality, and the 0.1 per cent proof stress also, without influencing the ultimate tensile stress appreciably. In the case of a high tensile alloy-steel strip the limit of proportionality and 0.1 per cent proof stress values were raised appreciably, the ultimate stress not being influenced appreciably. The bending properties of strip steel are usually reduced slightly by treatments of this type.

ELECTROLYTIC NICKEL COATINGS.

Heavy nickel deposits applied to steel surfaces cleaned by electrolytic pickling have been used for the protection of exhaust manifolds and pipes of engines, the protection being excellent at elevated and normal temperatures.

Since the efficiency of the protection afforded by protective metal coatings is influenced by the thickness of the coatings, mention should be made of methods employed to determine the thickness of the coatings. The thickness of a coating of cadmium, zinc, or nickel on steel may be conveniently determined in the following manner.

A sample of regular shape is taken and weighed. The area of coated surface in square centimeters is calculated from direct measurements. The sample held by a piece of aluminium wire is then immersed in a small quantity of cold concentrated nitric acid until all the metal coating has dissolved. When the action has ceased, the sample is removed from the acid and rinsed with water, the washings being collected in the beaker. The sample is finally rinsed with alcohol, dried, and weighed again.

A small quantity of iron is invariably dissolved away with the coating, due to local dilution of the nitric acid during the solution of the coating, and also during the subsequent rinsing. This is separated from the nitric acid with ammonia and determined volumetrically. This weight of iron deducted from the loss in weight of the sample gives the weight of metal coating. The weight of coating in grams divided by the density in grams per cubic centimenter gives the volume of the coating in cubic centimeters, and this in turn divided by the predetermined area of the coated surface gives the thickness of coating in centimeters.

The densities in grams per cubic centimeter are:

Cadmium	8.6
Zinc	6.9
Nickel	8.8

PROTECTION OF STEELS AGAINST OXIDATION AT ELEVATED TEMPERATURES.

The prevention of scaling of exhaust pipes and manifolds of aero engines is a problem which has received some attention recently. Among the various methods which have been investigated may be mentioned nickel-plating, "calorizing," aluminium-spraying, and aluminium-dipping.

In the case of electro deposits of nickel, coatings of the order of 0.003 to 0.005 inch in thickness are usually applied, the steel having first been pickled electrolytically. With this method there is the difficulty of securing a high degree of protection on the interior of manifolds, etc.

The "calorizing" process is one in which the steel parts, after having been cleaned by sand-blasting or other suitable means, are packed in a sealed container with a mixture consisting of aluminium powder, alumina, and a little ammonium chloride, and heated to approximately 680 degrees C. for 1 to 2 hours. At the surface of the steel an aluminium rich alloy layer is formed which affords considerable protection to the steel against scaling. The inner surfaces of manifolds and tubes receive a protective coating by this means, but distortion and the subsequent rectification required are practical difficulties frequntly met with in the application of this process to formed parts.

PROTECTION OF ALUMINIUM AND ALUMINIUM ALLOYS.

The aluminium-coated duralumin sheet, first produced commercially under the name Alclad, consists of a sheet of duralumin, each surface of which is covered by a coating of aluminium firmly alloyed to the underlying duralumin. As with duralumin, cold water is much preferable to hot as the medium for quenching in the final heat treatment of Alclad. The method of protection is one conveniently and effectively applied to sheets, and its use on tubes, bars, and sections appears to be a probable development. According to Rawdon (N.A.C.A. Tech. Note No. 305, p. 22) aluminium-clad duralumin, even when stressed, during corrosion, to a point very much above its endurance limit, gave results consistent with its superior behavior under other conditions. Under conditions of steady tension and simultaneous

exposure to corroding conditions, the initial properties were maintained unimpaired for 60 days when the stress was 20,000 pounds per square inch, but a few days' attack of unprotected duralumin stressed similarly caused a pronounced lowering in tensile properties. Brenner (D.V.L., Jahrbuch, 1929, pages 289-293) describes accelerated corrosion tests in the laboratory on Alclad samples; he found that the tensile strength of 1-millimeter sheets suffered only 2 per cent reduction, while that of duralumin sheet of the same thickness was reduced by 23.5 per cent. In three days' test the originally higher tensile strength of duralumin 1.5 millimeters thick had fallen to that of Alclad of the same thickness, which remained at its original value and continued so after five days' corrosion test, when the tensile strength of the duralumin was then nearly as much below that of the Alclad as it was originally above it.

ANODIC OXIDATION OF ALUMINIUM AND ITS ALLOYS.

Several methods of producing an oxide film on the surfaces of aluminium and its alloys have been developed for protection against corrosion. It is probable that the one which has been found of most general use in aircraft production is the Bengough anodic oxidation process.*

In modern anodic oxidation plants stainless-steel cathodes are frequently used. Formerly carbon cathodes were used, but it was found that the use of stainless steel resulted in a prolongation of the life of the bath, owing to the reduction of the chromic acid being less than at a carbon cathode. This development has caused an increase in the amount of gassing, and therefore also of the spray produced. Although the bath has a much lower concentration of chromic acid than a chromium-plating bath, the spray produced may cause trouble to the men operating the plant unless steps are taken to secure its removal. It is usually withdrawn from the space above the bath by means of a fan and a system of hoods and ducts.

Unlike some methods of surface treatment, anodic oxidation does not produce distortion of the material treated. Careful tests have consistently failed to reveal appreciable distortion.

An interesting and useful result arising from anodic treatment of parts is that with duralumin it is possible to distinguish between material which has been finally heat-treated and that which is in the softened condition, the anodic film of the finally heat-treated articles being appreciably darker than on softened material. Up to the present no solder has been found which will withstand anodic treatment really satisfactorily, but welded joints may be satisfactorily treated.

PROTECTION OF MAGNESIUM ALLOYS.

The protection of magnesium alloys against corrosion presents a difficult problem on account of the high chemical reactivity of magnesium.

Electro deposits of zinc or cadmium, which have been shown to be of great value in the case of aluminium alloys, appear rather to accelerate corrosion of magnesium alloys when in contact with saline solutions. The same results have been obtained with deposits of more noble metals than either of these. It is not, of course, practicable to plate magnesium with metals less noble than itself, as this would involve the use of metals such as calcium or barium, themselves too reactive for ordinary use.

* G. D. Bengough and H. Sutton, "Engineering," 1926, 122, pages 274-277.

It has not yet been found possible to produce a resistant oxide film on magnesium alloys by anodic treatment. In chromic-acid baths such as are used for the production of anodic films on aluminium alloys, the effect of using a magnesium anode is simply to produce soluble magnesium chromate. It is, however, possible to produce anodic films of high electrical resistance on magnesium alloys in fluoride, carbonate, aluminate, or phosphate baths, but these films, unfortunately, have only a small protective action against the corrosive effects of solutions of chlorides.

Much greater resistance to such corrosive agencies is obtained by films produced by chemical immersion processes involving the use of chromates. A bath which has been extensively used is one containing 10 per cent of nitric acid and 15 per cent of potassium dichromate, the work being immersed in the bath for a few seconds until the surface becomes of a clear brown color. This treatment gives a very fair resistance to corrosion under moderately severe conditions of exposure, particularly if the work be subsequently enameled with a cellulose enamel of good quality. A disadvantage of this bath, however, is that owing to its highly acid nature a considerable amount of metal is removed during treatment. This renders the method unsuitable for work which has been previously machined to fine tolerances.

A method of preparation which is free from this disadvantage, and which affords somewhat superior protection against corrosion, is to clean the work with 10 per cent nitric acid before machining, then to immerse the work for a short time in hot 2 per cent caustic soda, and then for six hours in a hot bath containing 1½ per cent of potassium dichromate, 1 per cent of potash alum, and ½ per cent of caustic soda. No appreciable dimensional change is observed when machined parts are treated by this method. The protective action obtained by chemical treatment in chromate baths would appear to be due to the production of a film on the surface of the metal of a compound of the approximate composition CrO_3, or chromic chromate. For the production of this film it appears necessary to have another acid radical present in the bath as well as the chromate radical.

GENERAL.

The snapped-up head of a rivet is usually more resistant to corrosion than the original head, and should, when possible, be put on the outside of surfaces exposed to water. This feature is observed in rivets in the various non-corroding steels, as well as in duralumin rivets which have been heat-treated and then quickly used.

When dissimilar metals are in contact and are moistened with an electrolyte such as salt water, the current set up will tend to cause attack upon one of the metals and to prevent attack upon the other metal. Between such materials as the so-called non-corroding steels and duralumin there is a considerable difference in solution potential. When these materials are in contact and are moistened with sea-water, the attack upon the duralumin is likely to be accelerated seriously. It is therefore necessary to seal carefully such joints as are necessary between these materials, and to exclude moisture as far as practicable. Efforts should be made to arrange for the two materials to be insulated one from the other, and the joint filled with non-absorbent material. Contact with copper alloys is usually much more vicious than is the case with the special steels, and is inadvisable if serious wetting with sea-water is liable to occur.—"Mechanical World and Engineering Record," October 30, 1931.

THE PURDUE HIGH-PRESSURE BOILER.

By A. A. Potter, Dean of Engineering; G. A. Hawkins, Assistant in Applied Mechanics; H. L. Solberg, Associate Professor of Mechanical Engineering.

The high-pressure boiler of today is still basically the same as that of fifteen years ago, although the use of economizers, air heaters and water-cooled furnaces has altered the arrangement of the heating surfaces. While present types of boilers could undoubtedly be built for still higher pressures by increasing the thickness of the parts, it is desirable from the standpoint of plant investment to develop a type of steam generator in which heavy drums, forgings and large pressure parts can be eliminated or at least reduced to a minimum. The high-pressure series steam generator installed at Purdue University is such a development.

The steam generator, Figure 1, consists of a cylindrical water-cooled furnace placed immediately beneath a counter-flow economizer, or convection section. The water which enters the unit passes through a continuous circuit and leaves as superheated steam. Outlet pressures up to 3500 pounds per square inch can be carried, and the same design of unit could be used for still higher pressures by the employment of suitable tubing of increased wall thickness. By varying the ratio of fuel to water at a given flow rate, the unit will discharge anything from warm water to 830 degrees F., superheated steam. The temperature is limited by the tube material used, but special alloy steels would allow operations at still higher temperatures. No throttle valves or other regulating devices are installed between the feed pump and the steam outlet.

A single Cuyama-type mechanical-atomizing oil burner is set in the floor of the cylindrical vertical furnace. The gases pass upward through the furnace and the single-pass convection surface to the stack. The heating surface, which consists entirely of a series of tubes in the form of coils mounted directly over the combustion chamber, is divided into a furnace wall, or radiant-heat-absorbing section, and an economizer, or convection section.

Feed water enters at the top of the convection section and flows downward, counter to the direction of gas flow, through two parallel circuits of equal length. This section is composed of 56 flat coils nested one above the other, each coil having seven straight parallel horizontal runs on 4-inch centers joined at the ends by integral 180-degree return bends. The terminating run of each coil is carried around the coil nest and into the second coil below it at the opposite corner. In this way alternate flat coils are connected into one of the two parallel circuits and the coils are further arranged so that the direction of flow of the water in the flat coils of one circuit is at right angles to that of the other circuit. The four flat coils at the bottom of this section are made with longer straight runs, which engage supporting members and thus carry the weight of the tube nest. Each of the two parallel circuits is 521 feet in length and is connected into a common equalizer, or downcomer, at the lower, or discharge, end.

Water from the convection section enters the furnace wall section at its low point and flows upward through two parallel circuits of tubes wound around the combustion chamber. The lower furnace wall section is wound in the form of a cylindrical helix, with sixteen complete turns in each of the two circuits. These circuits discharge into a common equalizer made of 1½-inch double-extra-heavy seamless steel tubing with a forged steel "Y" fitting welded to each end. This equalizer discharges into the two

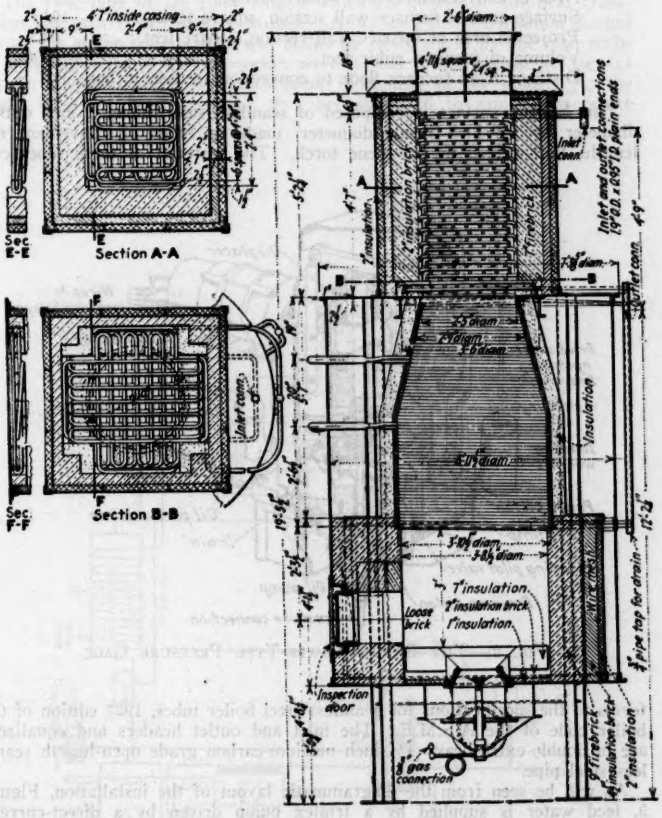


FIG. 1.—THE PURDUE HIGH PRESSURE TEST BOILER.

parallel circuits in the upper furnace wall section. These circuits are wound in the form of a conical helix, with eighteen complete turns in each circuit and with a second equalizer connection at the end of the tenth turn. The two circuits are connected into a common header at the outlet.

The heating surface of the steam generator is distributed as follows:

Area of convection section, square feet	259
Surface area of furnace wall section, square feet	101
Projected area of furnace wall section, square feet	64.5
Volume of furnace, cubic feet	84.4
Distance from furnace floor to convection section, inches	110

This heating surface is composed of seamless steel tubing 1 inch outside diameter by 0.5 inch inside diameter, made of tubes of convenient mill lengths butt-welded by acetylene torch. The material of these tubes con-

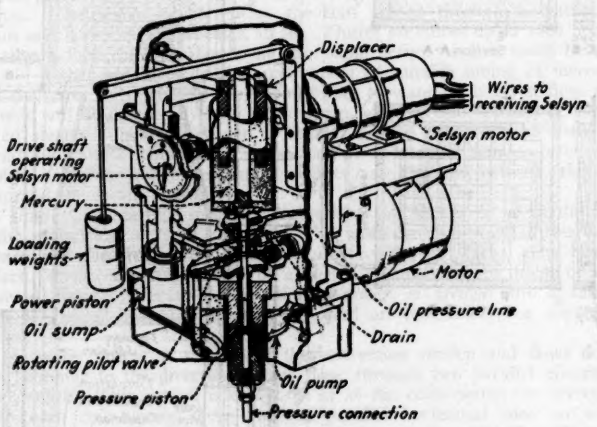


FIG. 2.—THE BAILEY POWER-TYPE PRESSURE GAGE.

forms to the specifications for seamless steel boiler tubes, 1927 edition of the boiler code of the A.S.M.E. The inlet and outlet headers and equalizers are of double-extra-heavy 1½-inch medium-carbon grade open-hearth seamless steel pipe.

As will be seen from the diagrammatic layout of the installation, Figure 3, feed water is supplied by a triplex pump driven by a direct-current variable-speed motor. The feed water from the pump discharge is heated in a special heat exchanger by the steam leaving the generator. From the heat exchanger the live steam enters a condenser of the steel tube floating-head type, designed for a pressure of 100 pounds. The condensate is weighed in closed steel tanks mounted on platform scales; these tanks are connected to the piping system by flexible hose. The condensate is checked by a flow meter.

Live steam from the laboratory header is passed through an auxiliary condenser for use as make-up water. On recommendation of the Babcock & Wilcox Company, trisodium phosphate is used to condition the boiler water. Tests are made on alternate days for total alkalinity, sodium phosphate and pH value of the water. Dissolved oxygen is also determined frequently.

The type of high-pressure valve and flanges employed is shown in Figure 4. The ring type of lap joint with a soft steel gasket of elliptical cross-section has proved satisfactory to date. A set of 2-inch companion flanges of this type at the boiler outlet was pulled up while warm by one man without sledging, using a 24-inch socket wrench, and it has shown no sign of leakage to date without any subsequent tightening of the studs. As the flanges have not been insulated, they are subjected to rapid temperature

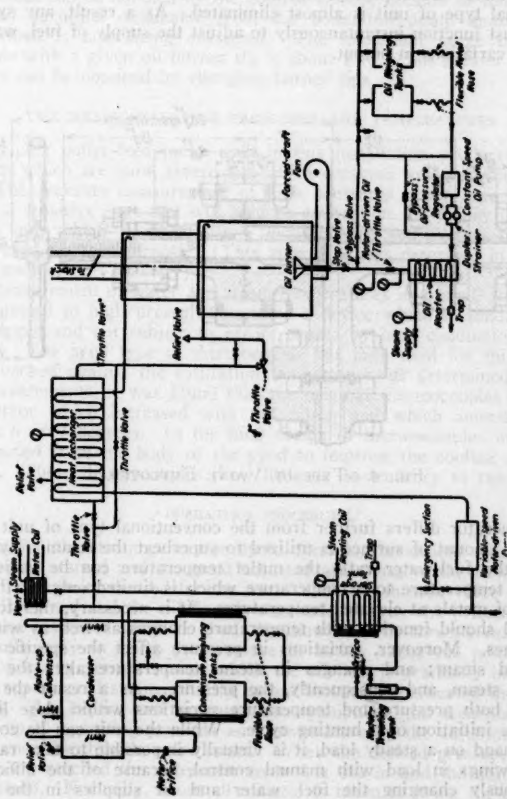


FIG. 3.—DIAGRAM OF THE TESTING EQUIPMENT.

fluctuations, especially on shutting down, when the temperature changes from that of superheated steam at full boiler pressure to the temperature of warm water within five minutes after the oil supply is shut off.

Several 6000-pound standard screwed forged steel tees are subjected to the full steam pressure and temperature; ¼-, ¾- and 2-inch screwed connections of this type were made up with No. 3 Smooth-On iron cement without back-welding and have shown no signs of leakage at any joint.

Double-extra-heavy Class B seamless steel tubing is used for the feed-water piping, while a chromium molybdenum steel-alloy tube is employed for the steam piping.

While the conventional type of steam generator has considerable energy storage in the drums and in the tubes, the series steam generator of Purdue University contains no drum, and the energy storage in the tubes is reduced to a minimum. Consequently, the accumulator action which exists in the conventional type of unit is almost eliminated. As a result, any system of control must function instantaneously to adjust the supply of fuel, water and air to the variations in output.

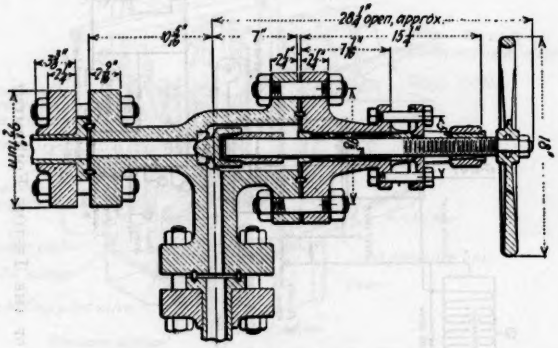


FIG. 4.—TYPE OF VALVE EMPLOYED.

This generator differs further from the conventional type of unit in that no definite amount of surface is utilized to superheat the steam. By merely changing the fuel-water ratio the outlet temperature can be varied from saturation temperature to a temperature which is limited only by the characterisics of metals at elevated temperatures. It is necessary, therefore, that the control should function with temperature changes as well as with pressure changes. Moreover, variations in pressure affect the specific heat of superheated steam; and changes in steam temperature alter the specific volume of steam, and consequently, the pressure. As a result the control must hold both pressure and temperature variations within close limits to prevent the initiation of a hunting cycle. While the unit can be controlled easily by hand on a steady load, it is virtually impossible to take rapid and repeated swings in load with manual control, because of the difficulty of instantaneously changing the fuel, water and air supplies in the correct proportions.

The system of automatic control developed by the Bailey Meter Company for controlling this unit employs the Thyratron vacuum tube circuit. Changes in pressure operate through Selsyn motors, the contractors in the circuits of two Thyratron tubes which supply power to a reversing direct-current motor geared to the oil throttle valve. Temperature changes similarly control the speed of the boiler-feed pump by causing a reversing direct-current motor to operate a rheostat in the shunt field circuit of the motor. A Bailey oil flow—air flow meter proportions the air to the fuel by operating the contactors in the circuits of another pair of Thyratron vacuum tubes which supply power to the reversing direct-current motor that operates the fan damper. Changes in throttle position operate the contactors in the vacuum tube circuits of both the fuel and water supply systems.

It has not been possible to determine the maximum instantaneous load changes that can be handled by the control system, because of limitations in the speed variation obtainable from the boiler-feed-pump motor, a condition which is now being corrected. The maximum range of capacity obtainable with a given oil burner tip is about 2 to 1, but greater variations than this can be obtained by changing burner tips.

THE MEASUREMENT OF PRESSURES AND TEMPERATURES.

The triplex boiler-feed pump used in this installation produces pressure pulsations which are quite severe and which continue well into the steaming zone. The accurate measurement of high pressures under such conditions requires a sensitive gage that will hold its calibration. A Bailey power-type pressure unit which is essentially a motor-driven self-loading deadweight gage is used for this purpose. (This apparatus was described in the April 4, 1931, number of "Power.")

The measurement of water and steam temperatures in a small thick-walled tube subjected to high pressures requires a device which is small, mechanically rugged and not subject to errors caused by heat conduction through the tube. The pyod type of thermocouple has been used for this purpose. When checked against the saturation temperature, as determined by pressure measurements, it was found that the original thermocouples read high by an error which increased with the rating and which amounted to as much as 6 or 7 degrees. In the final design of thermocouples more metal was removed from the body of the pyod to improve the cooling at the hot junction. These thermocouples show little or no tendency to read high.

OPERATING PROCEDURE.

In bringing the steam generator up to operating conditions from cold the feed pump is started and its speed adjusted according to the flow meter to develop the capacity desired for the test. With the throttle valve wide open the fire is lighted and the oil flow is regulated to raise the pressure to 1500 pounds and saturated steam in about 20 minutes. The throttle valve is then closed sufficiently to bring the pressure to within about 400 pounds of the desired operating pressure, after which the oil flow is gradually increased to produce superheated steam. As the steam becomes superheated the pressure increases. An experienced operator can manipulate the controls to bring the unit up to operating pressure and temperature by the adjustment of the oil feed once the throttle valve is set. When the desired pressure and temperature are reached the automatic control is cut in and the unit will take care of itself. Normally, about 40 minutes is taken to bring the cold boiler up to operating conditions and put it on automatic control, although it can be done by one man in 20 minutes.

In shutting down the unit the oil valve is closed, the dampers are shut and the boiler-feed pump is kept in operation. Within five minutes the steam gage will register the friction loss through the throttle valve and piping due to the flow of water. The pump is kept in operation for about 1½ hours longer, or until the brick furnace is black and the final water temperature is under 250 degrees.

Experience gained when putting the steam generator into service indicates the necessity for careful design and construction of units having several circuits in parallel in order that the resistances of the circuits shall be equal or adjusted to give flow rates which are proportional to heat absorption. Some unbalance exists in the two parallel circuits in the lower furnace wall section, resulting in the discharge of slightly superheated steam into the equalizer from one circuit while the other one is discharging saturated steam. Pressure measurements along the circuit in question have failed to show any localized point of high resistance. The unequal flow becomes noticeable only at high final steam temperatures and is not serious at any time.

Trouble has been experienced with the main steam throttle valve. The seat is made of Monel metal and is not damaged by steam-cutting, although the steam is throttled in this valve to a final pressure of about 50 pounds gage. However, the high pressure creates an unbalanced force which results in a mechanical galling or tearing of the valve seat when it is moved. As this is attributed to the softness of the metal, nitralloy seats will be tried in the near future.

The following series of tests has been conducted to date: 2500 pounds pressure, 750 degrees F. steam temperature, variable capacity; 2500 pounds pressure, constant capacity, variable superheat; constant capacity and final steam temperature, final pressures varying from 1500 to 3500 pounds; and 3250 pounds constant capacity and variable steam temperatures.

The efficiency of the unit is between 60 and 70 per cent, depending on operating conditions. The automatic control system functions satisfactorily under all of these conditions of operation and the unit is easily handled and is stable throughout the entire range of pressures and steam temperatures. —"Power," December 1, 1931.

BOOK REVIEW.

THE TRAGEDY OF *R-101*. By E. F. Spanner, London, E. F. Spanner, 9 Billiter Square, E. C. 3. 2 Vols. 42 Shillings Each.

Mr. Spanner is a well-known unbeliever in the practicability of airships. He has set forth his views in his earlier volumes, "This Airship Business," "Gentlemen Prefer Aeroplanes," and "About Airships." In his latest work, "The Tragedy of *R-101*," Mr. Spanner undertakes to prove that the *R-101* crashed to the earth as a result of breaking her back in the air; and not due to a sudden loss of gas, as concluded by the Court of Inquiry.

Mr. Spanner's point that the Court of Inquiry devoted far too little attention to the possibility of structural failure is well taken. The evidence showed that the gas retaining system was far from satisfactory; but a sudden gas loss of sufficient magnitude to have caused the fatal downward plunge could hardly have occurred unless a seam in a gas cell opened up, or a cell was damaged by some such structural failure as the collapse of a girder.

When Mr. Spanner comes to setting forth his own theory of the crash, he makes some astonishing jumps to conclusions unsupported by evidence. Most astonishing of all, he concludes that the ship broke by longitudinal compressive failure in her underside while turning upward, but not yet sufficiently turned to check completely the previous steep descent. Actually, the aerodynamic forces upon an airship while turning bend the bow and stern inwardly to the turn, except for the outward bending moment at the beginning of a turn produced by outward forces on the rudders or elevators. Consequently, during the upward turn, the ship would have tended to break in the direction opposite to that assumed by Mr. Spanner. If the *R-101* had encountered a gust of sufficient violence to buckle her lower longitudinals, she would have broken while turning downwards. In the subsequent recovery period, she could only have broken by sagging or compression on top. It is known that there was a recovery of several

seconds duration, since Mr. Leech, who was sitting in the smoking room, had time to replace various articles which slid off the table in the first dive. If the ship's back had been broken in that dive, it is improbable that there would have been any recovery.

According to Mr. Spanner, the immediate cause of the disaster was the ship running head on into a gust traveling at 66 miles per hour while she was passing through a lull at a ground speed of 36 miles per hour, producing a relative air speed of 102 miles per hour. It is not clear by what process of reasoning Mr. Spanner arrives at these figures; and there is not the slightest direct evidence to support them. Not only does Mr. Spanner assume a definite velocity at which the gust struck the ship, but he also assumes, entirely without evidence, that at the moment of encountering the gust, the ship was at 2 degrees downward pitch, with 4 degrees up elevator! In the face of such omniscience, how can one argue?

Very few facts can ever be definitely known about what actually happened in the *R-101* during the last minute in which she turned steeply downward, recovered, and then finally turned her bow to the earth. It is certain, however, that her mean air speed was not more than about 58 miles per hour. Due to alternations of gusts and lulls in windy weather, the air speed varies up and down from the mean value; but even a momentary increase of air speed approaching 44 miles per hour is extremely unlikely to have occurred in weather such as prevailed near the Beauvais Ridge that night. The U. S. S. *Los Angeles* has been flown with a recording air speed meter in winds so gusty that the ship was pitching 15 to 20 degrees up and down from the horizontal, but the air speed never rose more than 10 knots above the mean.

Undoubtedly, in gusty weather, the wind velocity over the ground varies far more than the variations in the relative air speed of an airship fighting its way through the gusts. The explanation is that although airship designers sometimes make the simple and safe assumption that gusts are instantaneous, they are not really so; consequently, the ship loses ground speed before a head-on gust reaches its maximum velocity, and the relative air speed is much less than the sum of the initial ground speed and the maximum gust velocity. The *R-101* was a heavier ship than the *Los Angeles,* and would lose speed less rapidly when entering a gust;

but nevertheless, an increase of 44 miles per hour in the relative air speed is altogether beyond the bounds of experience and probability in ordinary windy and gusty weather.

Having assumed the occurrence of a most improbable gust, and having broken the ship in the opposite direction to that in which she would be strained if going through the maneuver which he postulates, Mr. Spanner proceeds to a general attack upon the factors of safety provided by airship designers. Here he is partly right so far as the *R-101* is concerned. The design of that airship was based upon the recommendations of the "Airworthiness of Airships Panel," which was constituted to formulate minimum requirements for the strength of airships after the collapse of the *R-38* in flight. This committee dismissed rough air and gusts with the following brief paragraph:

"Information on the effect of gusts is so scanty as to be valueless for calculations, and the Panel has followed the lead given by the Accidents Investigation Sub-Committee in assuming that the worst conditions in a natural wind will not be more severe than those contemplated in the case of a ship flying in still air."

Observations with strain gages on the U. S. Naval Airships *Shenandoah* and *Los Angeles* have shown greater stresses in ordinary rough air flying than in any practicable still air maneuvers. The U. S. S. *Akron* is designed to encounter an instantaneous change of wind velocity of 56 feet per second (38 miles per hour) with a factor of safety of 2, based on the yield point of the material. Since no change of wind velocity is instantaneous, the specified condition based on our present knowledge seems ample for all exigencies short of running into a tornado.

Mr. Spanner complains that airships are designed for factors of safety of only 2, while 4 is required in other branches of engineering. This gives an entirely false impression that airship designers take chances that other engineers would not tolerate. The truth is that although insufficient allowance has often been made for the effects of aerodynamic forces, particularly in rough weather, the factors of safety applied to the calculated stresses are in accordance with accepted engineering practice. The airship factor of safety of 2 is based on the yield point of the material; whereas the factor of 4 in civil engineering is based on ultimate strength, which approximately corresponds to 2 on the yield point

for structural steel. In the design of vessels, Naval architects sometimes permit theoretical stresses as high as 10 tons per square inch for mild steel, which is a factor of safety of only about 1.5 on the yield point, or 3 on the ultimate strength. It is true that airship girders differ from mild steel structures in having very little margin between the yield point and the ultimate strength; but in seagoing vessels, this margin of strength is required to resist local damage, as when grounding. It is scarcely conceivable that a ship could survive storm conditions severe enough to produce an appreciable primary bending of the hull beyond the yield point or elastic limit. A bent bridge or skyscraper may also be considered a complete wreck.

Although the *R-101* was designed without theoretical regard to gusts, her designed strength was ample for ordinary gusty weather. How then can her fate have possibly been the result of structural failure? It is conceivable that a secondary longitudinal, which was designed only to support the outer cover, may have been broken by excessive vibration of the cover, and have pierced a gas cell. Another possibility is that a main longitudinal girder was not as strong as it was thought to be. These girders depended upon the initial tension in diagonal tension members to provide stability under compression. Few engineers would accept this construction as good practice; and although the laboratory strength tests of the girders were very satisfactory, it seems within the bounds of possibiliy that some of the diagonals did not have sufficient initial tension to prevent buckling of a primary girder under compressive loads much less than the designed crippling load of the girder. Failure of a longitudinal in the upper part of the ship might easily tear a gas cell, as well as greatly reduce the strength of the ship.

It must always remain conjectural whether or not structural failure was the cause of the disaster. Mr. Spanner gives much weight to the fact that the wreck had telescoped amidships about 50 feet on the under side. This is as likely to have been caused by the shock of striking the ground bow first, as to structural failure in the air. Moreover, Mr. Spanner naively states that he had formed his theory long before he obtained the evidence of the wreck.

C. P. BURGESS.

CHARLES A. McALLISTER

OBITUARY.

Captain Charles A. McAllister, U. S. Coast Guard, retired, formerly engineer in chief of the Coast Guard, and since his retirement president of the American Bureau of Shipping, died suddenly in New York on January 6, following a brief illness.

He was born in Dorchester, New Jersey, on May 29, 1867, and was graduated from Cornell University in 1887 with the degree of M. E. For some time he served in the drafting rooms of several of the large shipbuilding companies, and was later employed in the Bureau of Steam Engineering, Navy Department.

In 1892, Captain McAllister received a commission as second assistant engineer in the United States Revenue Cutter Service, now the Coast Guard. He saw active service during the Spanish-American war, and after being promoted through the various grades was appointed engineer in chief of the Revenue Cutter Service in 1906. He served in this capacity until his retirement in 1919.

After retirement, he became affiliated with the American Bureau of Shipping, first as vice-president and later as president of this Bureau. In this position of opportunity and authority his counsel and services were frequently sought in the settlement of important problems of administration and construction, especially in the conduct and maintenance of Government shipping. In the last decade with the American Bureau of Shipping he had an opportunity to encourage progressive ideas, and as president of this Bureau he was one of the United States delegates to the International Conference on Safety of Life at Sea, Load Line, Etc., in London during May, 1929. He was chairman of the committee appointed by the Federal Shipping Board to encourage increased economy in the machinery of the United States merchant fleet.

Captain McAllister has been an active member of the AMERICAN SOCIETY OF NAVAL ENGINEERS for over thirty years and for many years was a member of the Council. He was vice president of

the Society of Naval Architects and Marine Engineers, trustee of the Webb Institute of Naval Architecture, an associate member of the United States Naval Institute, and a member of the Chamber of Commerce of the State of New York, Engineer's Club, National Press Club, Naval and Military Orders of the Spanish-American War and executive committee of the American Marine Standards Committee.

He is the donor of the McAllister motorboat trophy, which is contested for annually by vessels of the Coast Guard for efficiency in gasoline engines, and also of the McAllister prize for engineering, awarded annually to the member of the graduating class of the Coast Guard Academy who has shown the highest average proficiency in engineering subjects.

Captain McAllister enjoyed a wide circle of friends both in public and private life and was held in the highest esteem and affection. His death has been a distinct loss to the country and to the Coast Guard.

ASSOCIATION NOTES.

ELECTION OF OFFICERS.

Ballots cast for officers of the Society for 1932 were counted on Wednesday, December 30, 1931. The following were declared elected:

President:

Rear Admiral Frank B. Upham, U. S. Navy.

Secretary-Treasurer:

Captain O. L. Cox, U. S. Navy.

Members of Council:

Rear Admiral S. M. Robinson, U. S. N.
Captain H. G. Bowen, U. S. N.
Captain R. C. Davis, U. S. N.
Captain H. S. Howard (C. C.), U. S. N.
Captain John Q. Walton, U. S. C. G.
Mr. W. M. McFarland.
Mr. J. F. Metten.

FINANCIAL STATEMENT.

The following is a financial statement for the calendar year 1931:

Receipts.

Publication:		
Dues	$5597.50	
Subscriptions	2583.05	
Sales	406.65	
Advertisements	3458.24	
Exchange	4.55	
		$12,049.99
Interest on investments		888.63
Current Profit and Loss		152.20
		$13,090.82

Expenditures.

Publication:			
Printing	$7323.52		
Engraving	1486.44		
Drafting	8.00		
Manuscript	890.00		
Postage	129.43		
Commission and Discounts	215.20		
		$10,052.59	
Salaries		2700.00	
General Expense		141.17	
Banquet, 1931		18.73	
			12,912.49
Net Gain			$178.33
Total Assets January 1, 1932			$20,008.48

MEMBERSHIP.

The following members have joined the Society since the publication of the last previous JOURNAL:

NAVAL.

Cottrell, Paul C., Machinist, U. S. N.

Kent, Edward M., Lieutenant, U. S. Coast Guard.

Maynes, Robert P., Lieutenant, U. S. N. R., 944 Club Avenue, Allentown, Pa.

Roth, Edward E., Lieutenant, U. S. Navy.

Weber, C. S., Ensign, U. S. N. R., Westinghouse Electric and Manufacturing Co., Washington, D. C.

CIVIL.

Stewart, William C., Engineering Experiment Station, Annapolis, Md.

Thompson, Lawrence, Engineering Experiment Station, Annapolis, Md.

ASSOCIATE.

Adams, Robert C., Jr., 96 McKendree Ave., Annapolis, Md.

Gardner, Arthur U., 4442 N. LaPorte Ave., Chicago, Ill.

Greenly, Col. J. H. M., Babcock & Wilcox Co., London, England.

Sivori, Juan J., Ing., Direccion General Del Material Bolivar 65, Buenos Aires, Argentine Republic.